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Marine Fouling and Borers

Editor

I. V. Starostin

Translator: M. Slessers
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1964-1965

G. B. Zevina, I. A. Kuznetsova and I. V. Starostin

THE STATUS OF MARINE FOULING IN THE CASPIAN SEA

Abstract

The macrofouling of the Caspian Sea is represented by 48 animal and 28 alga forms. In 1961 the leading forms of fouling included Balanus improvisus, Mytilaster lineatus, Dreissena polymorpha, Cordylophora caspia, Perigonimus megas, Corophium curvispinum, C. robustum, Electra crustulenta, Balanus eburneus, Mercierella enigmatica, and Bowerbankia imbricata. The majority of the above mentioned species penetrated into the Caspian Sea within the last five to six years. The appearance of new species has brought about a considerable increase in the density of fouling. In some regions the fouling was ten times heavier than before the penetration of new species.

At the present time, the greater portion of Caspian foulers are, by their origin, Mediterranean organisms that have recently moved into the Caspian Sea.

The leading forms of Caspian foulers in 1961 were the following species (listed in the order of their importance in fouling): Balanus improvisus, Mytilaster lineatus, Dreissena polymorpha, Cordylophora caspia, Perigonimus megas, Corophium curvispinum, C. robustum, Electra crustulenta, Balanus eburneus, Mercierella enigmatica, and Bowerbankia imbricata. B. improvisus, E. crustulenta, B. eburneus, and M. enigmatica have entered the Caspian Sea during the last six years; it is possible that P. megas and M. lineatus have appeared in the Caspian Sea about 40 years ago. Also B. imbricata is considered to be a Mediterranean form (Mordukhay-Boltovskoy, 1960a). Thus, the leading autonomous forms of Caspian foulers are only Dreissena, Cordylophora, Corophium curvispinum, and C. robustum.

The Mediterranean emigrants make up a considerable part of the secondary forms. Such foulers as Rhithropanopeus harrisii tridentatus, Nereis diversicolor, Syndesmya ovata, Leander adsperus, and L. squilla are very frequently found during recent years.

Since the new immigrants have settled in the Caspian Sea, the biomass of marine foulers has considerably increased (Zevina and Starostin, 1961; Zevina, 1962b).

Some of the new settlers have made a long trip, arriving not only from the Black and Azov Seas after the opening of the Volga-Don Canal leading into the Caspian Sea, but also prior to it, since R. harrisii tridentatus and Balanus eburneus had reached the Mediterranean basin from the American coast. Mercierella has also propagated all over the world during the last decades.

The greater portion of marine foulers can endure unfavorable factors of the medium and propagate over large areas. With the development of shipping, the transplantation from one sea to another, even from one part of the world to the other, has been very frequently observed. (The following species of marine foulers have traveled great distances to new settlements: Elminius modestus from Australia to the west coast of Europe and the mollusk Rapana bezoar from the Sea of Japan to the Black Sea, etc.). Therefore, on the basis of the main forms of marine foulers, they may, at the present time, be roughly divided into cold water, temperate latitude, and tropical forms, singling out in each group saline and brackish water forms.

Even the foulers of the Caspian Sea, which was isolated for a long time from the ocean, became, after the opening of the Volga-Don Canal, almost identical to the foulers of other seas or areas of seas lying in temperate zones and being considerably diluted.

As to the species composition, the Caspian foulers differ from that of the Sea of Azov only by the absence of the mollusk Stiliger bellulus and mytilids. The biomass of fouling is in both seas almost identical. True, in the area of the Sea of Azov, which is adjacent to Kerchenskiy proliv, the differences are greater. Thus, for instance, here are found mytilids and several other organisms. /4

The difference between the Caspian and Black Sea foulers are markedly greater. The species composition of Caspian foulers is by far poorer; also their biomass is smaller. The biomass of Caspian foulers is especially reduced by the absence of mytilids and tunicates. V. D. Brayko (1960) points out that 19 species of bryozoans inhabit the Black Sea, whereas at the present time we know only three species of bryozoans in the Caspian Sea, not including the fresh water forms. Approximately

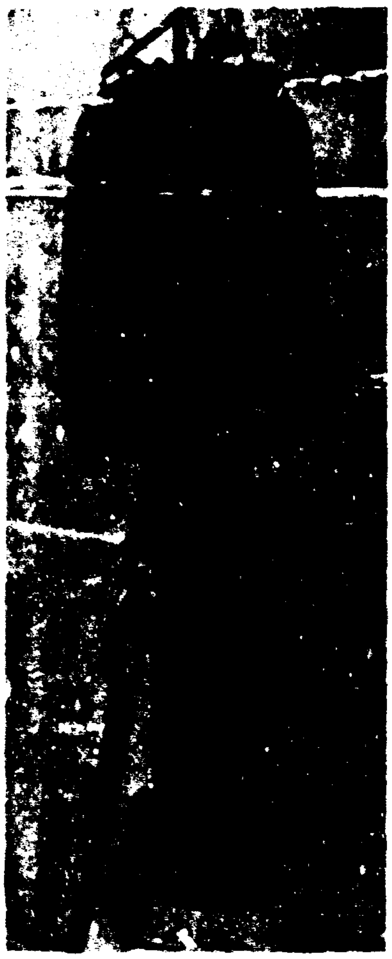

Fig. 1. A fouled buoy, which had been 7 months in the Caspian Sea. Photographed by G.B. Zevina.

the same relationship exists with respect to other groups of fouling organisms in the Caspian and Black Seas.

In the Caspian Sea the samples of fouling organisms were collected from 1951 to 1961 in various parts of the sea from the water's edge to a depth of 12 m. These samples were taken from buoys (fig. 1), wharves and stockades, bottoms of ship hulls, the inner parts of water pipes containing sea water, and from cliffs and boulders.

The algae were gladly identified by A. D. Zinova and N. I. Karayeva, bryozoans by M. G. Gostilovska and G. G. Abrikosova, chironomids by N. Yu. Sokolova, gammarids and corophiids by N. N. Romanova, mollusks by Ya. I. Starobogatov and N. N. Akramovskiy, hydroids by D. V. Naumov, and sponges were identified by N. V. Koltun.

DESCRIPTION OF THE DISTRIBUTION AND ECOLOGY OF ORGANISMS FOUND IN THE FOULING OF THE CASPIAN SEA

Principal Forms

Balanus improvisus Darwin (fig. 2) was first observed in the Caspian Sea in 1955 in the areas of ostrova Kulaly (Sayenkova, 1956) and the town of Isberg (Derzhavin, 1956). In the summer of 1956, the species was found all over the sea, except for several northwestern areas lying far off the ports (Zevina, 1957a). In 1960-61 B. improvisus was observed in all of the areas of the Caspian Sea, except for the most diluted sector. Such a rapid propagation of the species all over the sea is not unusual for cirripedian crustaceans. For instance, another crustacean, Elminius modestus settled in 1947 on the bottom of ships in the harbors of Great Britain having arrived from the shores of Australia.

In 10 years E. modestus already inhabited the coasts of Great Britain, France, the Netherlands, Belgium, Germany, Portugal, and Spain (Bishop, 1947, 1954; Stubbings, 1950; Hartog, 1953, 1956; Bishop and Crisp, 1957, etc.).

There is no doubt that B. improvisus entered the Caspian Sea by riding on the bottoms of ships passing through the Volga-Don Canal. The cirripedian crustaceans can close hermetically the covers of their shells, thus becoming isolated from the external medium. According to experiments conducted by E. P. Turpayeva and R. G. Simkina (1961), most individuals of this species perish in fresh water during the first 10 days, but certain individuals may exist in fresh water longer than 1.5 months. Consequently, the travel through the Volga-Don Canal was not difficult for them.

B. improvisus is a euryhaline organism. It is common in the estuaries of rivers, is found in Lake Paleostomi (Kudelin, 1913) and lives also in certain areas of Sivash, where the salinity of water fluctuates from 30 to 60‰ (Tarasov, 1927).

Fig. 2. Balanus improvisus on mytilaceans. Photograph by Lafoki.

Beginning with 1956, the barnacle was found on the bottoms of all the Caspian vessels. The shells of barnacles form a dense coating that is difficult to remove; the weight of the coating reaches 5-7 kg/m^2. The interstices between the shells of barnacles are settled by other organisms (mollusks, crabs, gammarids), which would be wiped off the hull without the protective covering of barnacles. Therefore the barnacles not only produce a large mass themselves, but they increase it by creating conditions for the existence of other foulers. Owing to the tight [illegible] of barnacles, they cannot be washed off even at great speeds [illegible] vessels.

On buoys the barnacles form adhesions consisting of as many as seven or eight layers on top of one another. Along the west coast of the northern sector of the Caspian Sea, the biomass of the barnacles on buoys reached almost 40 kg/m^2 during 7 to 8 months in 1958, but in 1960, when a considerable decline in the development of B. improvisus began, the biomass was only 22.5 kg/m^2. In the central and southern sectors of the Caspian Sea, the buoys, that had been in the water for 17 to 20 months in 1960, were covered by a mass of barnacles weighing 21 kg/m^2 According to a report by L. A. Zenkevich (1935), in Novorossiysk the biomass of B. improvisus reached 12 kg/m^2 in four months; V. N. Nikitin (1947) points out that the biomass of this species had reached 18-28 kg/m^2 on plates in four to five months.

Consequently, in the Caspian Sea, the biomass of B. improvisus is not smaller, but possibly even greater than in the Black Sea. As is typical of the entire fouling phenomenon (Zevina, 1962b), the biomass of barnacles in 1958-1960 reached a minimum value along the northeastern coast of the Caspian Sea.

If in 1956 (Zevina, 1957a) the shells of B. improvisus had a conical form and thick walls and were strongly reminiscent of the shells of B. eburneus, in 1958-1961 the shells of most were reminiscent of lilies or sticks. /6

The barnacles evidently do not propagate all year round in the Caspian Sea, because even in the warm Krasnovodskiy zaliv the plates were not fouled by barnacles in the winter. In the Sea of Azov, B. improvisus propagates all year round (Vorob'yev, 1949). According to data by M. A. Dolgopol'skaya (1959), this barnacle can, in considerable quantity, settle on hydrotechnical structures rising at a distance of 12 to 15 miles from the coast, fouling them from the surface to a depth of 70-80 m and possibly deeper. The same was observed by us on buoys in the Caspian Sea that had been placed at a considerable distance from the coast, though in shallow water.

At the present time, B. improvisus is undoubtedly the main fouler in the Caspian Sea, being especially harmful because of rapid development.

Mytilaster lineatus Pall. was first observed in the Caspian Sea by V. V. Bogachev (1928a, b) in 1928 in the area of Apsheronskiy poluostrov. It is thought that the species was introduced from the Black Sea by the hulls of ships transported by railway from the Black Sea into the Caspian Sea. By 1932 the mytilaceans ranged along the south, east, and west coasts of the Caspian Sea, reaching the southern portions of the northern sector of the sea (Brotskaya and Netsengevich, 1941).

Prior to the appearance of barnacles, the mytilaceans were the main foulers in the Caspian Sea. After the appearance of B. improvisus the of M. lineatus decreased, notably in the early stages of development, although it cannot be said that the number of the mytilaceans has decreased. In the northern sector of the Caspian Sea the number of the species depends on salinity, varying considerably from year to year (Zevina, 1958).

In 1953, when the salinity in the northern section of the Caspian Sea was moderate, the mean mass of M. lineatus on buoys was 16.4 g/m^2; in 1958, as the salinity decreased greatly, the biomass became 2 g/m^2; after the salinity increased again, the quantity increased to 398 g/m^2, (see fig. 3), in 1960.

After the appearance of barnacles, the quantity of mytilaceans has increased on wharves and plates in the Izberg area of the central sector of the Caspian Sea, but on the west coast of the southern sector of the sea, the quantity of mytilaceans decreased considerably in 1958 for reasons unknown to us; the amount increased somewhat in 1960, but did not reach the level of 1953 (Zevina, 1962b).

Barnacles usually dominate in fouling that is in existence for less than a year, but later the mytilaceans take the upper hand. Barnacles grow at a very rapid rate, in two months they reach maturity, while mytilaceans are at the time still undeveloped, being not more than 3-4 mm long. They conceal themselves in interstices between the shells of barnacles, where they find protection from intense wave motion and benthos-eating fishes. At that time they do not bother the barnacles. But in one to two years, when M. lineatus becomes mature under the protection of barnacles, they begin to eliminate barnacles. It is possible that this occurs for the reason that mytilaceans begin to filter an increasing amount of water as they grow up. According to data by R. K. Kudinova-Pasternak (1951), M. lineatus of various sizes filter from 0.29 to 0.41 ℓ/per hour. Assume it is 0.35 ℓ/per hour and multiply it by the mean number of mytilaceans inhabiting 1 m^2, which is about 300,000. The result is that 1 m^2 of solid matter fouled by mytilaceans filters 105,000 ℓ of water per hour, or 2,250,000 ℓ per day. K. A. Voskresenskiy (1948) demonstrated that the water filtered by mytilids and mytilaceans loses the detritus suspended in it because part of the detritus passes thrrugh the intestines, while all the other particles, passing through the pallium, form agglutinations. It is natural that the animals, which live side by side with the filter-feeding bivalve mollusks, receive filtered water. Barnacles create only an insignificant flow of water with their legs and can in no way compete with mollusks. Therefore, no matter what species participate in fouling, the bivalve mollusks begin to dominate in the end.

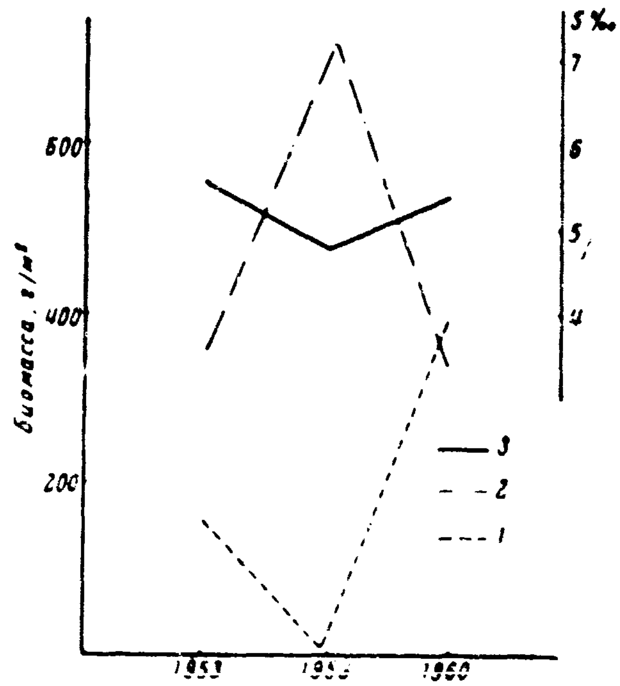

Fig. 3. The mean biomass of mytilaceans (1) and dreissenians (2) in the northern sector of the Caspian Sea, and the mean yearly salinity (3) in the surface layer in ostrova Tyuleniy area in 1953, 1958 and 1960.

Key. Abscissa: biomass, g/m^2

Sometimes the succession is irregular, for instance in the surf zone along the coast, where the mollusks cannot live and therefore the barnacles predominate (Raja, 1959).

Dreissena polymorpha (Pall) is the main fouler in the northern Caspian sector, i.e. in the part of the sea which is not inhabited by mytilaceans. Dreissena distincta inhabits the central and southern Caspian sectors; according to data by N. N. Romanova (1960), this fouler is the second significant species in the aquatic fauna. We never observed D. distincta in coastal fouling, probably, for the reason that it lives at greater depths than the ones investigated by us (to 12 m). D. polymorpha is found in fouling of the northern Caspian sector along its west coast to the Sulak River; along the east coast it is found as far as Bautino, because along the west coast the salinity is lower due to the discharge of Volga water.

The dreissenian biomass in the northern Caspian sector is characterized by a wide range of fluctuation in various years, depending on salinity and being inversely proportional to the biomass of mytilaceans (fig. 3).

In the northern Caspian sector the dreissenians cover stones, cliffs, hydrotechnical structures, as well as the hulls of vessels (D'yakonov, 1925, 1927). There are numerous indications that this mollusk inhabits fresh water basins.

On the buoys, that stay in the northern Caspian sector for a period of seven to eight months, the biomass of dreissenians is sometimes very great, reaching 13 kg/m^2; however, the average is 300–700 g/m^2. /8

Cordylophora caspia (Pall) (fig. 4) is found all over the Caspian Sea on buoys and hydrotechnical structures. The only exceptions are places where the degree of pollution is high, as for instance in Bakinskiy zaliv and on the wharves of Krasnovodsk. Because the vessels are often anchored in polluted locations, the C. caspia is seldom found on the hulls of vessels. We found the species only on vessels that navigated in clean waters, for instance on the motor boat "252" of the southern Caspian or on the vessel "Medvezhonok", when it was navigating between Astrakhan' reyd and stantsiya Makhach-Kala (Vtoraya portovaya).

The hydranths of cordylophores were found in northern Caspian sector in December, but in the southern Caspian sector they were found also in January and even in the beginning of February. Gonophores are not found in winter. Cordylophora did not settle on panels submerged in

Fig. 4. Cordylophora caspia in fouling taken from the buoys of the northern Caspian sector. Photograph by G. B. Zevina.

Krasnovodskiy zaliv in winter; only in April did it appear in great numbers. In Hamburg one can find only empty tubes of cordylophores in winter (Hentschel, 1916). According to Kinne (1956a, b), the reduction of hydranths in C. caspia occurs at temperatures below 2-4°.

The rate of fouling by C. caspia is rather rapid. Thus, on 15 July 1954, in Isberg the biomass of cordylophores on a panel that had been submerged in water for 35 days was 22 g/m^2, on 6 January 1955, on a pole that had been in water for four months, the mass equalled 705 g/m^2, but on buoys that had been lying on water for eight months in the north Caspian sector, the biomass of hydroids reached 3 kg/m^2 (it is possible that also Perigonimus megas was together with C. Caspia). During the growth season the biomass of cordylophores reaches a maximum value. A greater biomass was not observed on wharves and buoys that had been in water for several years.

If one examines the distribution of cordylophores by depths to 12 m, it is seen that their colonies begin below the zone of algae and are distributed almost uniformly to the bottom. The uniformity of this distribution is interrupted only at places where Mytilaster lineatus forms attachments in which the number of hydroids is considerably smaller. The hydroids cover not only objects lying in the water mass but also those lying on the bottom; thus, for instance, the concrete plates serving as anchors for buoys were covered by cordylophores (mollusks were almost completely absent).

Cordylophores are euryhaline animals which can take the salinity fluctuations that are usual for the Caspian Sea, and they can be found in almost pure water to the salinity of 14°/oo. On the basis of tests conducted by Roch (1924) it is seen that the optimum salinity for cordylophores ranges from 1 to 5°/oo, but the species can exist at salinities ranging from 0.3 to 10°/oo. Kinne (1956a, b) points out that the salinity limits for cordylophores inhabiting the Kiel Canal is 1 to 10°/oo. In the Caspian Sea the species lives in waters having higher salinities, for instance in Krasnovodskiy zaliv where the salinity is 14°/oo. In the northern Caspian sector, where the salinity is lower, cordylophores are found in a considerably greater quantity than in the central and southern Caspian sectors.

In some places, where cordylophores had once been found, they do not exist any longer, as for instance in Kiel Bay and Bakinskiy zaliv. It is associated with the fact that cordylophores are very sensitive to chemical contents and the oxygen found in the water (Roch, 1924), and that they cannot live in polluted water or in water with a small amount of oxygen.

Traveling with ships, the cordylophores have penetrated not only the rivers of the Caspian basin but also the rivers of the Baltic and Atlantic basins (Mordukhay-Boltovskaya, 1957). The species has also been found in the Dnepr water basin, but only in places where the mineralization of water is increased (Zhuravel', 1959). At the present time, they are found in seas surrounding North and South America, Australia, New Zealand, and China, mainly in areas adjacent to large sea ports where they are brought in by ships (Zenkevich, 1947).

<u>Perigonimus megas</u> Kinne was first identified in the Kiel Canal and described by Kinne (1956b). Kinne states that <u>P. megas</u> was found together with cordylophores and because externally they are somewhat similar, <u>P. megas</u> had not been identified before; therefore many authors have described the species as <u>C. caspia</u>.

In 1959, <u>P. megas</u> was found by I. V. Starostin, E. P. Turpayeva and R. G. Simkina in sea water near Zhdanov (Sea of Azov), where it formed large accumulations.

In the fall of 1961 we found the species on the hulls of vessels SCHS-202 and SCHS-225, which were engaged in fishing and navigated from Krasnovodsk to Sal'yanskiy reyd and Gasan-Kuli. The species was also found on crabs obtained in the Lenkoran' area in the summer of 1961 by N. Pavlova. An examination of the old collections from the Caspian Sea demonstrated that in 1958-1961 the species inhabited buoys together with cordylophores. <u>P. megas</u> was not identified before. It is, however, possible that it was found in the Caspian Sea before, because the greater portion of our collections were not obtained in the winter when this species does not have hydranths and it is difficult to tell the species from *Cordylophora*.

According to data by Kinne (1956b), which are supported by observations of Turpayeva and Simkina, as well as by our observations, *P. megas* differs from *C. caspia* by the following main characteristics: 1) in *P. megas* the feelers form a circle, but in *C. caspia* they are scattered all over the body of the hydranth; 2) *P. megas* has a hydrotheca, which is absent in *C. caspia*; 3) the female gonophores of *P. megas* have only one egg, while those of *C. caspia* have 1 to 14 eggs.

The capitula of polyps of *P. megas* become degraded at temperatures below 9-12° (Kinne, 1956a, b), i.e. this species is more thermophilic than *C. caspia*, which loses hydranths if the temperature is below 2-4°. Indeed, in October - December we found *C. caspia* with hydranths on buoys in the Caspian Sea when the temperature was about 5-7°, while *P. megas* was found only in the form of empty stolons.

The salinity at which the species was observed in the Kiel Canal /10
ranged from 1 to 10°/oo; in the Sea of Azov it was observed at salinities ranging from 3 to 5°/oo, but in the Caspian Sea it was found in waters with salinities as high as 14°/oo.

Because in the Sea of Azov *P. megas* is one of the main species participating in the fouling of the water supply system, it can be assumed that the species is found in the water conduits of the Caspian Sea.

The biomass of *P. megas* on vessels navigating in the Caspian Sea was relatively small — up to 220 g/m^2.

Corophiids (fig. 5). *Corophium robustum* O. G. Sars, *C. curvispinum* O. G. Sars, *C. nobile* O. G. Sars, *C. monodon* O. G. Sars, and *C. mucronatum* O. Sars were found in the fouling of the Caspian Sea. The first two of the species are widely distributed and they often form a large biomass. The other species were relatively seldom observed, mainly along the east coast of the Caspian Sea.

A large quantity of corophiids was found on a buoy in ostrov Chechen area of the northern Caspian sector (284,000 ind. per m^2) on

9 December 1953; the buoy had been in the water eight months. The greatest biomass of corophiids on the buoy was 500 g/m^2, the weight with shells being 3340 g/m^2. On some buoys the shells of corophiids

Fig. 5. A layer of shells of corophiids taken from a buoy in the northern Caspian section. Photograph by G. B. Zevina.

formed a dense layer 1 cm thick, as in the case of buoy No. 66 that had been in the water of the northern Caspian section for eight months when it was taken out by the end of November 1953.

In the Izberg area of the central Caspian section, greater amounts of corophiids were found - as many as 125,000 ind/m^2 and 420 g/m^2. To the south, in the Apsheronskiy poluostrov area, rather large quantities of corophiids were found on buoys along Shakhova kosa, where their quantity reached 21,000 ind/m^2, the biomass being 44.5 g/m^2. Small /11 quantities of corophiids were found on buoys along ostrov Zhilogo*. Still farther to the south only small quantities of corophiids were observed. On the east coast the number of corophiids was great. Thus, on a buoy in the entrance to zaliv Aleksandr-Bay, the quantity of the crustaceans reached 202,000 ind/m^2, the corresponding biomass being 272 g/m^2. A multitude of corophiids was also found on buoys in Krasnovodskiy zaliv (Krasnovodskaya bukhta).

It is noteworthy that in some cases the quantity of corophiids on certain buoys was exceptionally great, while on other buoys lying nearby the quantity was either very small or nil. Also Caspers (1952) observed in Helgoland that the amount of fouling varied considerably on buoys lying near one another. He attempted to explain it by assuming the existence of hypothetical larvae of foulers in water, which find a buoy or a spot on it and miss the other buoy or spots on them. Of course, the larvae are not uniformly distributed in the water, which affects the infestation of buoys or other objects.

It is, however, possible that a great influence is exercised by the saturation of water with oxygen to the lack of which the corophiids are very sensitive (Romanova, 1956b). Also the suspended organic matter and petroleum products found in polluted waters affect corophiids. They are never found in waters that are heavily polluted, as for instance in Bakinskiy zaliv (Bakinskaya bukhta). Corophiids were not found on the numerous wharves along the coast of Krasnovodskiy zaliv, where the water was heavily polluted; the same was true of a buoy anchored at a distance of 0.6 km from the coast, while on a buoy anchored at 1.6 km from the coast and other buoys in the area, the number of corophiids was great.

It is probable that for this reason, i.e. because corophiids do not endure pollution, they were not found in fouling on vessels because they are usually moored in more or less polluted waters. Only on motor boats and on felucca "Shtil", that were anchored in the strait leading to zaliv Kara-Bogaz-Gol, where the current was rapid, bringing fresh well aerated water, did corophiids (C. curvispinum and C. robustum) constitute the main mass of fouling. Their numbers on the motor boat reached 6870 ind/m^2, the corresponding biomass being 19 g/m^2. A. L. Bening (1924) found domes of C. curvispinum in the fouling on ships in the Volga River.

As is seen from the foregoing, the biomass and quantity of corophiids in the Caspian fouling are very great. According to data by Ya. A. Birshteyn (1953), the numbers of each species of corophiids did not

*Not listed in the NIS Gazetteer.

exceed 1000-1300 ind/m^2 in the benthos of the northern Caspian sector, while in the fouling they constituted 284,000 ind/m^2, as we saw it earlier. N. N. Romanova (1956b) notes that C. robustum makes up 1000-2000 ind/m^2 of the fouling, while in the samples taken by bottom grabs its quantity does not exceed 20 ind/m^2.

The quantity of corophiids varies greatly from year to year. Thus, the average biomass of corophiids in the fouling of the northern Caspian sector made up 119 g/m^2 in 1953, 156 g/m^2 in 1958, and 40 g/m^2 in 1960. Romanova (1956a) thinks that one of the causes for the fluctuation in the amount of crustaceans in the northern Caspian sector is the disturbance of the gas regime, the other cause being consumption by fishes. It is possible that the small quantity of corophiids in the fouling of the northern Caspian sector in 1960 is due to consumption by crabs, which appear here in large quantities.

Populations of corophiids reminiscent of those observed in the fouling /12
of the Caspian Sea were observed by F. D. Mordukhay-Boltovskoy (1948) on clay and solid objects in the Dnepr delta. Their numbers reached 2000 ind/m^2.

Jassa pulchella (Caspers, 1952) plays a great role on buoys anchored along Helgoland; its quantity (to 300,000 ind/m^2) corresponds to the quantity of corophiids in the Caspian Sea. The J. pulchella settlements reach a thickness of 1-2 cm, and they are found everywhere on buoys, except for the thin surface layer. In the Caspian Sea, corophiids are also found at the sea surface in places where algae grow; however, their numbers are small. In the lower zone of algae their numbers are very great; at greater depths, the corophiids cover objects more or less uniformly to the bottom.

Thus, the fouling of corophiids is not of great significance for vessels. However, they are quite frequent on hydrotechnical structures in clean waters. In the latter case, these crustaceans, when found in large quantities, are used as food by fishes. We observed more than once that fishes were feeding at buoys and wharves covered by the domes of corophiids.

In the Caspian Sea, Electra crustulenta (Pallas) was first observed in November - December 1958 in Krasnovodskiy zaliv and in Bautino area (Zevina, 1959). E. crustulenta is widely distributed in brackish water basins along the sea coast of Europe and North Africa, in the Baltic

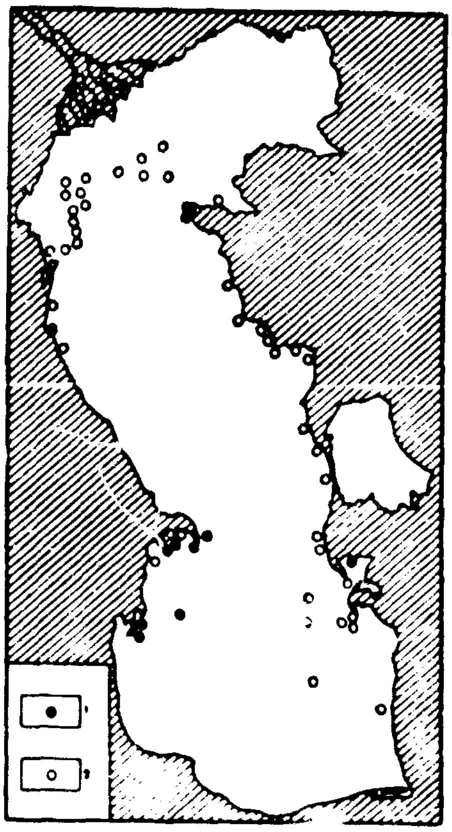

Fig. 6. Locations where E. crustulenta was found in the winter of 1960/1961 on buoys and hydrotechnical structures.

1 — found; 2 — not found

and Black Seas. G. G. Abrikosov (1959b) thinks that this species was pointed out by V. P. Borob'yev (1949) for the Sea of Azov under the name of Membranipora sp. E. crustulenta can endure 2-3°/oo of salinity. In the southern Caspian sector it lives at salinities as high as 14°/oo.

In 1958 this bryozoan was found only in two localities, in 1960-1961 it was found in 13 locations (fig. 6). All the inhabited localities were located in areas of large ports or where navigation was developed. Along the west coast, E. crustulenta was observed in the port of Makhach-Kala, in Bakinskiy zaliv (Bakinskaya bukhta) area and in Sal'yanskiy reyd, but along the east coast the species was observed only in Krasnovodskiy zaliv and on buoys in the Bautino area. In 1960-1961 E. crustulenta was very frequently found in fouling on vessels. This makes its distribution understandable. This species can obviously travel only by vessels. It is possible that the larvae of this bryozoan cannot be transferred far due to its short life span in plankton.

Borg (1931) describes several forms of the species. We found in the Caspian Sea a form that was closely reminiscent of baltica Borg, but also another, possibly a new form is found, which has two small spines in front. /13

In some cases E. crustulenta grew densely over barnacles and mytilaceans, covering at times the protective valves of barnacles. If a colony was developed in a limited space, folds and festoons were formed.

The biomass of E. crustulenta was as a rule small, about 20-30 g/m^2, but in individual cases the quantity of 900 g/m^2 was reached (on a buoy in the Kiel Canal).

Sometimes the settlements of the bryozoans occupied 40—50°/$_0$ of the surface of hulls of vessels. Most frequently the diameter of the settlements was short, ranging from 3 to 5 cm; but some of the settlements had a diameter 30-40 cm long. On the bottoms of vessels, the biomass of the bryozoans reached 500 g/m^2 (on RR-516).

Usually the places occupied by E. crustulenta were relatively free of other foulers. If the bryozoan occupied the hull's surface before other foulers, only a few organisms had a chance to settle there. It is possible that dense bryozoan populations cause the death of barnacles. the bryozoans settled less frequently on places occupied by mytilaceans.

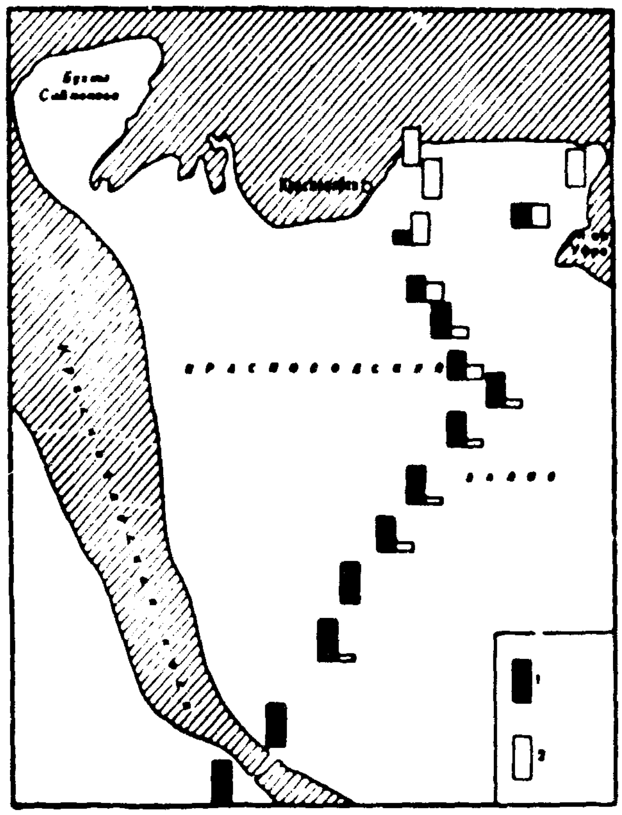

Fig. 7. Relationship in percentages between the quantity of B. improvisus and B. eburneus on buoys in Krasnovodskiy zaliv.

1 — B. improvisus, 2 — B. eburneus. The length of column at the presence of only one species equals 100°/o.

Geographical names, clockwise, from upper left hand corner: bukhta Saymonova - Krasnovodsk - poluostrov Ufra - Krasnovodskiy zaliv - Krasnovodskaya zaliv.

Balanus eburneus Gould was for the first time noticed in Krasnovodskiy zaliv and on ostrov Ogurchinskiy in 1956 (Zevina, 1957a,b). According to observations by I. V. Starostin, this species appeared in Krasnovodskiy zaliv en masse only in the summer of 1956. Later it was found also on the west coast of the sea in the gulfs of ostrov Artema area, which are protected from wave action and are more or less polluted (Mordukhay-Boltovskoy, 1960b). This is not the first migration of B. eburneus. The phenomenon was noted by A. Ostroumov in 1892 in the Black Sea. He thinks that this species has been brought by ships from America. Ecologically, B. eburneus differs from B. improvisus because the former avoids areas with rapid currents and therefore it is not so frequently found on the bottoms of vessels. B. eburneus was found in large numbers only on vessels that had been staying for a long time in Krasnovodskiy zaliv, often together with B. improvisus. The biomass of B. eburneus on navigating vessels was above 1 kg/m^2, but on anchored vessels and at wharves to 20-30 kg/m^2.

Large individuals of the species up to 28 mm long and 25-28 mm high were observed on a sunken barge in Krasnovodskiy zaliv.

According to Grave (1933), B. eburneus begins to reproduce at the age of two months. The barnacles were not found on panels submerged in Krasnovodskiy zaliv and examined in April; in June their number was rather great, and their length reached 9 mm. They seemed to be no older than a month, because the B. eburneus that inhabits the Black Sea reaches the length of 15 mm in two months, and we have no reason to assume that the growth rate of the barnacles is decreased in the Caspian Sea: there were no symptoms of stunting. In the Beaufort ⌈N. C.⌉ area B. eburneus forms settlements from the middle of March to December (McDougall, 1943); probably, in the Caspian Sea the settlement of larvae of this species does not take place in the winter.

The absence of this species in the northern Caspian sector and the Sea of Azov is noteworthy. Dilution can hardly prevent the progression of the species to these areas because B. eburneus has been found not only in the estuaries of rivers, but even about 50 miles upstream in the rivers of Florida (Tarasov and Zevina, 1957). It is most likely that the progression of the species northward is obstructed by low winter temperatures.

In Krasnovodskiy zaliv, B. eburneus is found only in the port area, while B. improvisus inhabits open places of gulfs, which are not polluted. The replacement of one species by the other can be well traced by the buoys placed at various distances from the town.

Mercierella enigmatica Fauvel was for the first time observed in the Caspian Sea by Zevina (1961, 1962a) in November 1960. The tubes of the species were found among the fouling on the hulls of two vessels (scow No. 12 and steamer "Komsomolets"). Both of the vessels were navigating only in the Caspian Sea. The scow No. 12 was navigating first in Krasnovodskiy zaliv, later in Bakinskiy zaliv; whereas the steamer "Komsomolets" navigated between Baku, Krasnovodsk, and Bektash. A detailed investigation of marine fouling on buoys and vessels in Bakinskiy zaliv, as well as in the northern and southern portions of the Caspian Sea, disclosed the absence of M. enigmatica. Evidently, this species appeared at the beginning in Krasnovodskiy zaliv. True, in the winter of 1960-61 we did not find M. enigmatica on the buoys and wharves in Krasnovodskiy zaliv, but we succeeded in finding it on a small cutter navigating in the gulf.

A year of investigation of marine fouling on vessels and hydrotechnical structures in Krasnovodskiy zaliv made it clear in October 1961 that M. enigmatica had become a mass form in Krasnovodskiy port. The species was found in compact settlements on wharves, piers, and hulls of ships that were moored at the piers of Krasnovodsk. Large accumulations of the fouler were observed on piers of passenger vessels and in their immediate area; however, the number of M. enigmatica was small in the northern part of the port — at fishing wharves and piers for small boats. On test panels the species began to appear since June, so that one may think that it began to propagate en masse in May.

In the fall of 1961, M. enigmatica was not yet found on buoys placed in Krasnovodskiy zaliv and in nearby areas — at banka Zhdanova, banka Livanova, zaliv Kara-Bogaz-Gol, and on piers at Kianly. Neither was the species found on the hulls of vessels docked in October 1961 at Baku and navigating in Bakinskiy zaliv or standing at Sal'yanskiy reyd*.

M. enigmatica is found along the shores of the Atlantic, Indian, and Pacific Oceans, as well as in the Mediterranean, Black and Azov Seas. During the last years it has appeared along the east coast of Australia (Allen, 1953). However, the distribution of the species is not uniform. In the opinion of a number of authors, M. enigmatica has propagated over large areas only relatively recently by traveling on the bottoms of vessels.

M. enigmatica is usually associated with low salinity areas of seas, such as bays, river estuaries, canals with brackish water, and brackish lakes. According to data by Turpayeva (1961), the species is capable of living and reproducing in salinities ranging from 6-7‰ to almost /15 oceanic values. Consequently, this species can live in the central and southern Caspian regions, as well as in the southern part of the northern Caspian region. The travel of M. enigmatica via the Volga-Don Canal was possible because, according to investigations conducted by K. S. Arbuzova (1957), M. enigmatica can endure fresh water as long as two to three months.

*Not listed in the NIS Gazetteer.

This fouler settles on the bottoms of vessels, on hydrotechnical structures, as well as within water conduits in the sea. According to data by Nikitin (1947), the number of the foulers settled on test panels in Poti area reached 175,000 per 1 m^2. One can assume that the species, together with barnacles, mollusks, and hydroids will dominate in marine fouling of the Caspian Sea.

Bowerbankia imbricata (Adams) caspia Abrikosov and Victorella pavida S. Kent are usually found together (Abrikosov, 1959a). However, the former prevails in marine fouling. Therefore the bryozoan biomass listed below pertains mainly to this species.

Bryozoans appear to be the main foulers in Bakinskiy zaliv and on vessels navigating or staying in the gulf for longer time periods. They were also found at ostrov Artema, ostrov Zhiloy (o. Zhilogo), in Krasnovodskiy zaliv, and in several other places, provided they were heavily polluted.

In Bakinskiy zaliv, all the piers below the waters edge are completely covered by a brown spongy layer of bryozoans. The bryozoans are absent only in areas where industrial waste waters are found.

The test panels submerged for five months at mys Bailov were covered by a layer of bryozoans weighing 150 to 600 g/m^2.

On the hulls of ships, the smallest amount of bryozoans was found on the bow, a greater amount in the mid-section, and the greatest amount on the stern. The bryozoan biomass also increased toward the bottom. On ships that had not been docked for several years the bryozoan biomass reached 2.3 kg/m^2. However, a uniform fouling by these bryozoans is not a great obstacle against the motion of the ship, because it does not create friction, but, on the contrary, may make the surface fouled by barnacles and mollusks smoother.

Secondary Forms

Protozoans. Very frequently protozoans (ciliated infusorians of Peritricha) were found in Bakinskiy zaliv, on piers at Izberg, and in Krasnovodskiy zaliv. Large quantities of them were on the hulls of vessels standing in Bakinskiy zaliv. According to S. N. Probatov, in areas where the sewage water of the city was drained into Bakinskiy zaliv large numbers of infusorians (Vorticella microstoma, Carchesium lahmanni and Zoothamnium sp.) were found. On the panels submerged in Krasnovodskiy zaliv near the waterworks of the sea canal of the petroleum plant, the protozoan colonies were the first ones of animals to appear in winter. They were not found in November and December on panels that had been submerged for one month; in January and February small amounts of them were observed, but in March a continuous white fluffy cover having a biomass of 13-16 g/m^2 was found. In April, macrofoulers settled on the panels and therefore it was difficult to determine the quantity of protozoans.

Sponges are found in fouling on stones, cliffs, and mollusks at depths exceeding 12 m; therefore they were not found by us. However, a multitude of sponges was found along the entire east coast; they had been cast ashore by storms and were identified by V. N. Koltun as Metschnikowia tuberculata var. tuberculata Grimm and M. tuberculata var. intermedia Grimm.

Roundworms were found in almost all of the samples of fouling taken from vessels and from stationary objects in various areas of the Caspian Sea at all the depths that were examined. The weight of their fouling was insignificant.

Oligochaetes of the family Enchetreidae were found in small quantities in fouling on the cliffs of mys Melovoy and in fouling on stationary objects in Bakinskiy zaliv.

Nereis diversicolor Comb. was introduced into the Caspian Sea in 1939-1940 and is now found in fouling on stationary objects almost everywhere, except for polluted and low salinity areas. The number of N. diversicolor on buoys reached 1500 ind/m^2, the maximum length of specimens being 88 mm. G. M. Belyayev (1953) notes that the biomass of N. diversicolor reached 870 g/m^2 in lagoons and bays of ostrova Tyulen'i; however, we did not observe such a great biomass. These worms live in salinities exceeding 4-5‰ and can well endure an oxygen deficit (Birshteyn and Spasskiy, 1953; Karpevich and Osadchikh, 1953); a considerable number of fishes uses the worm as food (Birshteyn, 1953; Sokolova, 1953).

Fabricia sabella (Ehrenberg) was found en masse in fouling samples taken from stones and wooden piers along the east coast of the Caspian Sea - namely, in Krasnovodskiy zaliv, Bektash, and in the strait leading to zaliv Kara-Bogaz-Gol. Because of a small size, the significance of the worms in fouling is small. Probatov found F. sabella in the fouling of Bakinskiy zaliv.

Crustaceans. In addition to corophiids and cirripedians, which are most significant in fouling, we have often found crabs, gammarids, shrimps, and harpacticids. The latter forms were observed in various areas of the Caspian Sea, even in heavily polluted waters but, due to small sizes, their significance in marine fouling is limited.

Gammarids. The following gammarids were identified in marine foulings: Carinogammarus caspius, Dikerogammarus haemobalphes (Eichwald), D. aralensis Ulj., D. caspius Pall. Dikerogammarus sp., Pontogammarus abbreviatus G. O. Sars, P. robustoides G. O. Sars, P. crassus G. O. Sars, P. obesus G. O. Sars, P. subnudus G. O. Sars, Pandorites platychier G. O. Sars, Amathillina affinis G. O. Sars, A. cristata O. Sars, and Gmelina costata O. Sars. The most common were D. haemobaphes and P. robustoides.

It was not possible to count accurately the number of gammarids in marine fouling because they left their settlements as soon as the test panels, buoys or vessels were taken out of the water; however, sometimes the number that remained on the objects reached several hundreds per 1 m^2. It can be assumed that they accumulate by the thousands in fouling, due to which the fouling composed of gammarids attracts fishes.

The gammarids were never found in heavily polluted water. Neither S. N. Probatov nor we found them in Bakinskiy zaliv. Neither the foulings of navigating vessels contained these crustaceans; probably, these lively animals are washed off when the vessel is on the move.

Leander adspersus Rathke and L. squilla (L.) were found in large quantities in algal foulings, especially near the coast; but owing to their mobility, it was difficult to catch them. Never were they found in polluted waters.

Rhithropanopeus harrissii subsp. tridentatus (Maitland) (fig. 8) appeared for the first time in the northern Caspian sector in 1958 (Nebol'sina, 1959). In the winter of 1958/59 it was found in the /17
fouling on buoys in the northern Caspian sector and in the western part of the central Caspian sector (Zevina, 1959). When investigating the marine fouling in the winter of 1960/61 we found the crab on almost all of the buoys in the northern Caspian sector, in the areas of Apsheronskiy poluostrov, and south to Lenkorani (fig. 9). At the time, the species was not yet inhabiting Krasnovodskiy zaliv, where it appeared en masse only by the beginning of 1961 (on the basis of oral report by the personnel of Turkmenian Fisheries Laboratory). In October 1961 we found the crab in Krasnovodskiy zaliv in large quantities. Even on the hulls of ships standing at Krasnovodsk the number of the crabs was great: 600 to 1200 individuals were observed per 1 m^2 on the bottom of SCHS-225.

The distribution of the mobile crabs, whose larvae float in the water for a long time, differed substantially from the distribution of bryozoans whose larvae are characterized by brief planktonic development. In two years the bryozoans were observed in areas of large ports and active marine communication. Crabs progressed during the same time by sticking to the hulls of ships, spreading their settlements from each new spot in a relatively short time by traveling along the sea bottom, while their larvae were distributed by currents. Therefore, the crabs have occupied greater areas than the bryozoans in regions that are seldom visited by ships.

Fig. 8. Rhithropanopeus harrisii tridentatus from Lenkorani area. Photograph by V. Nartsisov.

Rh. harrisii broadens its inhabited area again and again. Ya. A. Birshteyn (1952) reports that in 1951 the crab was found by V. V. Murina in the Baltic Sea. A. K. Makarov assumed that the crab by sticking to the hulls of ships arrived at port Nikolayev from where the animal penetrated Bugskiy liman and Dneprovskiy liman. F. D. Mordukhay-Boltovskoy (1952) observed the crab in the lower reaches of the Don River. In the water pipes of Azovstal' (Azov-Steel; in the Sea of Azov) the crabs are found en masse, polluting their filters and clogging the cooling system.

The appearance of the crab in the Caspian Sea will undoubtedly affect the number of crustaceans for which Rh. harrisii can be considered as a competitor. It is possible that the quantity of gammarids, corophiids, oligochaetes, and polychaetes will decrease, which will affect adversely the feeding of fishes.

Caddis flies. According to F. F. D'yakonov (1925), the larvae of caddis flies are usually observed in the fouling on ships in the lower reaches of the Volga. The larvae of Hydropsyche ornatula build their tubes not only on the surface of objects but they also gnaw niches, where they live and cover themselves with lids made of wood pasted together with glues they produce. According to calculations by the author, the number of niches on the bottom of barges averages 2.5-3 thousands per m^2.

We found the tubes of larvae of caddis flies in the fouling of the "Kirovets" navigating in the Astrakhan' area.

Tendipedes. A great quantity of larvae was found on the barge "Sevan" navigating in the lower reaches of the Volga and the northern Caspian sector and on the steamer "Khariton Laptev", which had navigated about one and one-half months in the Volga. Pupae of *Endochironomus gr. tendens* F. and *Cricotopus* gr. *silvestris* F., as well as larvae of *Cricotopus* gr. *algarum* Kieff. *C.* gr. *latitendatus* Tshernovskiy were observed on these ships.

Fig. 9. Findings of *Rhithropanopeus harrisii tridentatus* in the winter of 1960/61 on buoys and hydrotechnical structures in the Caspian Sea.

1 — the crab was found;
2 — the crab was not found.

Single specimens of larvae of *Smittia* sp. were found in the central Caspian sector on the cliffs of the east and west coasts of mys Melovoy and on iron piers at Izberg.

Bivalve mollusks. Cardiids (mainly *Cardium edule*) and *Syndesmya ovata*, which had traveled from the Caspian and Azov Seas together with nereids, were often found in foulings. Cardiids and syndesmyans are found among the accumulations of mytilaceans and dreissenians, which hold the former by byssal cords. The quantity of cardiids in fouling that were several years old reached 2000 ind/m^2, the corresponding weight being 151 g/m^2. Usually small specimens, about 1-2 mm long, were found in foulings; however, sometimes also specimens as long as 11 mm were observed. These foulers were observed at depths from 2 m and below, i.e. in layers where mytilaceans and dreissenians predominated. Especially great numbers of cardiids were on the upper sides of rings mounted on the tubes of buoys because, evidently, in these places it was easier for them to stick.

Gastropod mollusks. *Hydrobia grimmi* Clessin are found only along the bottom — on boulders and lower sections of piers. The species was observed in

Izberg and ostrov Artema areas. At Sumgait, the species was found in the water supply pipes. In ostrov Artema area the number of the mollusks reached 25,900 ind/m^2 on boulders. Theodoxus pallasi Lindholm was found only on boulders lying on the bottom of the sea, on lower sections of piers and on panels in the following locations: Izberg, mys Sagyndyk, ostrova Svinoy, Artem, "Kamen' Ignat'yeva". The number of specimens reached 8300 per m^2.

In the fouling of the pit of sea waterworks at Sumgait one individual of Clessioniola variablis Eichw. and one of Micromelania sp. were found.

Ova of Fish. A multitude of ovae — probably of sea robins — was found firmly fixed to a board of a tide guage at ostrov Ogurchinskiy.

Algae. Diatom algae were identified by N. N. Karayeva (1961). Altogether 121 forms were found on the west coast of the Caspian Sea; 49 species were found for the first time in the Caspian Sea.

Diatom algae were found almost in every sample taken from a shallow depth, for instance to 3 m, sometimes deeper, making up at times a considerable biomass — as many as several hundreds of grams per 1 m^2. Considerable quantities of diatoms were observed in the fouling on ships. An especially great amount of the algae was found on a mechan- /19
ically propelled crane, on the cutters "Liza Chaykina" and "Ul'yana Gromova", on the barge "Sevan", the vessel "Khariton Laptev" and on the planks of boats standing at ostrov Zhiloy. These algae were mainly distributed over well lighted portions of vessels.

Considerable quantities of diatoms were also found on buoys. The biomass of diatoms on buoy No. 50 was 760 g/m^2 at a depth of 1 m on 27 November 1953, but on buoy No. 73 the biomass was 1690 g/m^2 at a depth of 10 m on 7 December 1953: the fouling of diatoms was 1-1.5 mm thick.

Usually, at a certain depth, the biomass of diatoms is somewhat greater than on the surface. Thus, for instance, on December 9, 1953, the biomass of diatoms on buoy No. 74 was 60 g/m^2 at a depth of 20-30 cm, and 545 g/m^2 at a depth of 1 m. Often the tubes of corophiids were so densely covered by diatoms that they appeared to be green.

The increase in the mass of diatoms is rapid. Thus, on panels placed near Izberg the following variations in the magnitudes of diatom algae were observed: during 19 days (from 20 May to 8 June ,1954) the biomass increased to 61.6 g/m^2; during 35 days (from 10 June to 15 July) the biomass increased to 200 g; during 45 days (from 10 June to 25 July) the amount reached 146 g; during 90 days (from 8 May to 8 July) the amount reached 645 g.

Thus, it can be seen that the diatoms play a significant role in marine fouling of the Caspian Sea, as in the case of other seas, with respect to biomass but mainly with regard to the rate of development.

Blue-green algae were found less frequently than the diatom algae and they almost never formed large accumulations. Only on the steamer "Pioner", navigating in the southern Caspian sector, did we find 405 g/m^2 on the lower part of the midship section.

As a rule, the biomass of blue-green algae was comparable to that found on buoy No. 50 at the depth of 2.5 m — namely: 1.4 g/m^2 — and on piers at Izberg on 22 June 1955 at the depth of 2.5 m — namely: 3 g/m^2.

According to unpublished data by S. N. Probatov, the following representatives of the family Oscillatoriacea were found in Bakinskiy zaliv: Spirulina major Kutz, Sp. subtilissima Kutz, Sp. tenerrima Kutz, Sp. labyrinthioformis Menegh, Oscillatoris tenuis Ag., Osc. Amphibia Ag., Osc. putrida Schmid, Osc. nigroviridis Thwait., Osc. margaritifera Kutz, Osc. limosa Ag., Osc. subuliformis Kutz, Osc. brevis Kutz, Lyngbia martensiana Menegh., L. aestuarii Liebm. and L. semiplena Ag.

Generally, the blue-green algae found in the fouling of Bakinskiy zaliv have relatively rapid rate of growth.

Green Algae. Fourteen species of green algae were found in marine fouling; some of them were identified for the first time in the Caspian Sea.

Usually, the green algae grow below the level of diatoms. The depth of the levels depends upon illumination. As a rule, the biomass of green algae was greater than the biomass of the other algal groups. The mean biomass of green algae constituted several hundreds of grams per 1 m^2, but also a mass of several kg per 1 m^2 was found. Thus, on a buoy that was floating at banka Makarova (southern Caspian sector) for about two years, the biomass of green algae was 3450 g/m^2 at the depth of 15 cm, but on buoy "Pogorelaya plita" (southern Caspian sector) that was in the water for seven months, the biomass equalled

2207 g/m^2. The rate of development of the fouling was generally considerable, reaching on the bottoms of ships 2-3 kg/m^2. However, as a rule, the biomass of green algae on ships fluctuated from 200 to 300 g/m^2.

The green algae formed bands on the hulls of ships along, and slightly below, the water line. The width of the band depended on the form of vessel: if the plank was slanting, the band was not broad, usually several cm; if the plank was vertical, the width of algal band reached several meters.

LIST OF ALGAE

Acrochaete parasitica Oltm. was found once on Laurencia of the floating lighthouse in Astrakhan' reyd on 28 November 1953.

Ectochaete leptochaete (Huber) Wille was observed twice — on Cladophora covering mys Melovoy on 25 November 1953 and on ostrov Svinoy on 10 July 1955, i.e. on the east and west coasts of the central Caspian sector in summer and late fall.

Ulothrix sp. was observed in Bakinskiy zaliv on 6 July 1953, on buoys along Shakhova kosa on 8 February 1954 and on banka Kornilova-Pavlova* on 24 January 1954, on ostrova Svinoy on 10 July 1954 and on Kamen' Ignat'yeva on 14 July 1954, as well as on the large motor cutter "Kuznechik" on 16 July 1953, operating mainly in Bakinskiy zaliv. Thus, the species is found in winter and summer seasons in Apsheronskiy poluostrov area and a little to the south of it, as well as in the heavily polluted Bakinskiy zaliv, which is indicative of its polysaprophytic character.

Enteromorpha intestinalis (L) Link was found on ostrov Svinoy on 10 July 1954, in Lenkoran' on 12 July 1954, and along the east coast of mys Melovoy and mys Sagynzyk (Sagyndyk?) on 25 November 1953. In addition, the species was observed on vessels, as for instance, on the steamer "Tsuryupa" on 4 July 1953, on the mechanically propelled crane vessel No. 13 on 14 July 1954, and on a mechanically propelled crane on 6 July 1954. A study by S. Ya. Veysig, B. Ya. Al'per and Ya. L. Shapiro (1934) explains the absence of E. intestinalis in Bakinskiy zaliv by the effect of petroleum on the species, because this algae is not only found in polluted city waters but it even prefers such waters. Also, the studies by T. F. Shchapova (1938), and M. S. Kireyeva and T. F. Shchapova (1939a, b; 1957a, b) mention the observation of this species in various parts of the Caspian Sea. According to data by the authors, E. intestinalis is luxuriously developed in polluted waters of Krasnovodskiy zaliv.

*Not listed in the NIS Gazetteer.

Enteromorpha tubulosa Kutz. was found in Bakinskiy zaliv on 6 July 1953, and on cutters "Baykal" on 11 July 1954 and on "Semen Ostapenko" on 17 November 1953. Both of the cutters were operating mainly in Bakinskiy zaliv. The species was not found in clean waters.

Enteromorpha clathrata (Roth) I. Rg. was found in Lenkoran' on 12 July 1954 on piers and vessels: on a self-propelled crane on 6 July 1954 and on BM-31 on 16 November 1953, where the biomass of the alga equaled 202 g/m^2 in the mid-section of the vessel. This form is indicated by Kireyeva and Shchapova (1957a) for the Caspian Sea (according to data by Volkov and other authors).

Enteromorpha salina Kutz. was observed in Izberg on 8-9 October 1951, 13 November 1953, 6 January 1955, on ostrov Svinoy on 10 July 1954, on ostrov Kamen' Ignat'yeva on 14 July 1954, on ostrov Peschanyy on 24 November 1954, on buoys at Shakhova kosa on 8 February 1954 and at banka Makarova on 23 January 1954, as well as on the following vessels· on 8 July 1953 on a motor boat, on 4 July 1953 on the steamer "Tsuryupa", and on 8 July 1953 on the cutter "Ul'yana Gromova". This species is widely distributed over the central and southern Caspian sectors and can be observed in various seasons.

Enteromorpha sp. was found in Bakinskiy zaliv on 6 July 1953.

Monostroma latissimum (Kutz) Wittr. was found by us for the first time in the Caspian Sea in October 1961. Great quantities of the form were observed in Krasnovodskiy zaliv at the time. M. latissimum was also found in zaliv Kara-Bogaz-Gol. It is evident that the species has only recently settled in the Caspian Sea, because neither we had discovered it before, nor any of the earlier investigators had indicated the existence of the species in the sea.

Rhizoclonium kochianum Kutz. was found in Bakinskiy zaliv on 6 July 1953, in Izberg on 8-9 October 1951, on 10 July 1954 on ostrov Svinoy, on 12 July 1954 in Lenkoran', on 6 July 1953 on motor boat 252. Kireyeva and Shchapova (1957a, b) found the species on the east coast of the Caspian Sea and in Krasnovodskiy zaliv. One may think that this species tolerates pollution. /21

Chaetomorpha aerea (Dillw) Kutz. was found by us only once; namely, on 10 July 1954 on ostrov Svinoy. Also Kireyeva and Shchapova (1957a) indicate the existence of this species (according to data by L. I. Volkov and other authors).

Cladophora glomerata (L) Kutz. is found throughout the Caspian Sea, often constituting a part of the algal fouling. The species was observed in Izberg on 8-9 October 1951, 13 October 1953, and 14 December 1953, on the floating lighthouse of Astrakhanskiy reyd on 28 November 1953, on a buoy in zaliv Aleksandr-Bay on 22 November 1953, on poluostrov Peschanyy on 24 November 1953, on a buoy at Shakhova kosa on 8 February and 5 July 1954, on a buoy at banka Makarova on 23 January 1954, and on the southeastern side of ostrov Zhiloy on 5 July 1954. In addition, Cl. glomerata was observed on a self-propelled crane on 6 July 1954, which operated in the area of ostrov Zhiloy, ostrov Neftyanyye Kamni, etc., i.e. in places where pollution is relatively limited. S. I. Kolosova (1935) notes that in the Volga River C. glomerata is limited to well aerated waters. L. A. Belogolova (1946) found the species among the foulers of vessels operating in the Baltic Sea.

Cladophora sp. was found on buoys at ostrov Nargin on 22 January 1954, at Shakhova kosa on 5 July 1954, on ostrov Svinoy on 10 July 1954, and on Kamen' Ignat'yeva on 14 July 1954, as well as on cutter "Irtysh" operating in the areas of ostrov Zhiloy and Neftyanyye Kamni.

Cladophora fracta (Dillw.) Kutz. was observed on a self-propelled crane on 6 July 1954.

Brown algae are seldom found in marine fouling [Ed. note: in the Caspian Sea], and if they do occur, the quantity is insignificant.

Ectocarpus confervoides f. fluviatilis Kutz. was found on buoy No. 73 on 27 November 1953, and on a buoy at banka Makarova on 23 January 1954.

Ectocarpus (?) was found on poluostrov Peschanyy on 24 November 1953, on the hull of the motor boat "252" on 3 July 1953, and on the cutter "Irtysh" on 14 November 1953.

Compsonema (?) was observed on the hull of cutter "Ul'yana Gromova" on 3 July 1953.

Entonema oligosporum (Stromf) Kylin. was found on the floating lighthouse in Astrakhanskiy reyd where this alga had settled on Laurencia and Ceramium.

Red algae were often observed in marine fouling, but less frequently and in smaller quantities than the green algae.

Asterocytis ornata was observed at ostrov Svinoy on 10 July 1954 and Kamen' Ignat'yeva on 14 July 1954, as well as on a self-propelled crane on 6 July 1954.

Acrochaetium thuretii (Born) Coll et Herv. was observed in Izberg on 26 June 1953 and on 6 January 1955, on ostrov Svinoy on 10 July 1954, Kamen' Ignat'yeva on 14 July 1954, on buoys at banka Kornilova-Pavlova on 24 January 1954, and on banka Makarova on 23 January 1954, and on a self-propelled crane on 6 July 1954. Kireyeva and Shchapova (1957a) indicate the existence of the species along the east coast of the sea, and zaliv Komsomolets and zaliv Kaydak.

Acrochaetium daviesii (Dillw.) Nag. was found at Izberg on ? October 1951, on buoys in zaliv Aleksandr-Bay on 22 October 1953 and on banka Kornilova-Pavlova on 24 January 1953, as well as on small cutters; namely, on the rudder of the "Ul'yana Gromova" on 8 July 1953, and on the bottom of the "Irtysh" on 14 November 1953.

Ceramium diaphanum (Lightf.) Roth. was found in large quantities at Izberg on 14 December 1953 and on 6 January 1955, on the floating lighthouse in Astrakhanskiy reyd and on almost all of the buoys in the northern Caspian sector in the winter of 1953, along the east coast during 22-25 November 1953, and in the following localities: mys Melovoy and Sagyndyk, poluostrov Peschanyy, and on a buoy in zaliv Aleksandr-Bay. The species was also observed at poluostrov Svinoy. /22

M. S. Kireyeva and T. F. Shchapova (1957a), who were working in the Caspian Sea during 1934-1938 and in 1941, did not find this species. Only in 1952 when A. K. Sayenkova (1956) collected algae in the northern Caspian sector, she found numerous C. diaphanum and C. tenuissimum (?). Thus, it can be assumed that this species appeared relatively recently in the Caspian Sea. At the present time it is one of the most widely distributed and abundant algae. C. diaphanum is not found in polluted places; possibly, that is the reason the species was not encountered on navigating vessels.

This algae was found in especially large numbers in the winter. According to data by N. V. Morozova-Vodyanitskaya (1930), this species is reproduced in Novorossiyskiy zaliv by sexual means from November to May, but by asexual means from April to June; from July to October the species does not reproduce.

I. V. Starostin found the species in the area of the State Regional Electric Power Plant of Northern Baku, where the algae jam the filtering structures of the waterworks, especially after strong storms.

Ceramium sp. was found on a buoy in zaliv Aleksandr-Bay on 22 November 1953.

Polysiphonia elongata (Huds.) Harv. was observed on wharves at Izberg on 8 October 1951, at ostrov Svinoy on 10 July 1954 and in zaliv Aleksandr-Bay. Kireyeva and Shchapova (1939a, b; 1957 a, b) found the species in various areas of the Caspian Sea.

Polysiphonia variegata (Ag.) Zana d. was found in zaliv Aleksandr-Bay on 22 November 1953, and on ostrov Svinoy on 10 July 1954.

Polysiphonia sp. Fragments of the algae were found on ostrov Svinoy on 10 July 1954 and on Kamen' Ignat'yeva on 14 July 1954, on the floating lighthouse in Astrakhanskiy reyd on 28 September 1953 and on a self-propelled crane on 6 December 1954.

Laurencia paniculata (Ag.) Kutz. was found at Izberg on 26 June 1954, and on a buoy at Banka Kornilova-Pavlova. Kireyeva and Shchapova (1939a,b; 1957a, b) had observed the species in various areas of the Caspian Sea.

Laurencia sp. Fragments of the species were found on ostrov Kamen' Igant'yeva on 14 July 1954 and on the floating lighthouse in Astrakhanskiy reyd.

Except for one species, all of the listed algae were identified by A. D. Zinova by examining our collections obtained prior to 1955; the remaining collections are still being processed. According to Zinova, 12 species of the collections are new for the Caspian Sea: Acrochaete parasitica, Ectochaete leptochete, Enteromorpha tubulosa, Monostroma latissimum, E. salina, Ectocarpus confervoides, Ectocarpus (?) Compsonema (?), Entonema oligosporum, Acrochaetium daviesii, Ceramium diaphanum and Polysiphonia variegata.

When the samples obtained during 1956-1961 have been processed, many new species brought into the Caspian Sea by ship bottoms, after the opening of the Volga-Don Canal, will undoubtedly be determined.

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MASS DEVELOPMENT OF THE POLYCHAETA MERCIERELLA ENIGMATICA FAUVEL IN KRASNOVODSKIY ZALIV

Abstract

Mercierella enigmatica was brought to the Caspian Sea from the Black Sea and the Sea of Azov on ships bottoms. In December 1961 the bottoms of launches which had sailed in the Krasnovodsk Bay for four months were heavily covered with Mercierella, its biomass being up to 30 kg/m^2.

In recent years the immigration of new species into the Caspian Sea from the Azov and Black Seas has been observed. Thus, for instance, single specimens of Mercierella enigmatica were observed in 1961.

By the beginning of December 1961 large quantities of the species were observed on the hulls of little-used wooden cutters when they were taken out of the water.

All the underwater parts of the cutters, which had been cleaned on 27 July 1961, were overgrown with a thick layer of tubes of M. enigmatica — propellers, wooden bushings, propeller shafts, rudders formed a monolithic mass of marine fouling (Fig. 1 and 2).

The greatest length of individual tubes of M. enigmatica reached 13.5 cm. The mean length of the tubes was 10.9 cm; consequently, the average monthly accretion equals 2.7 cm (the cutters were in the water not longer than four months).

The samples scraped from an area of 100 cm^2 made it possible to calculate the mean raw weight of marine fouling which equaled 29.75 kg/m^2.

Consequently, with the total underwater surface being 36 m^2, each of the 10 ton cutters had accumulated 1080 kg of additional weight during the four months, which was contributed by M. enigmatica. But if we take into consideration the fact that a dense layer of Balanus improvisus, B. eburneus, Mytilaster lineatus lies beneath the layer formed by M. enigmatica, in which live also numerous crabs Rhithropanopeus harrisii tridentatus, shrimps Leander squilla, L. adspersus, the mean weight of fouling increases to 40 kg/m^2; thus, the corresponding increase of unneeded weight of the vessel reaches two tons.

The appearance of M. enigmatica in the Caspian Sea and its mass reproduction will possibly increase the high rate of fouling on vessels and port structures in Krasnovodskiy zaliv, because these foulers appear also on other types of vessels (SChS, AME, etc.) with steel hulls, though in a considerably smaller quantity, which is evidently associated with the utilization of the vessels.

Fig. 1. The general view of marine fouling on propeller blades (part of fouling has been removed, barnacles are seen).

Fig. 2. Shaft and rudder overgrown with tubes of *M. enigmatica*.

N. I. Karayeva

DATA ON THE FLORA OF DIATOM ALGAE IN MARINE FOULING ALONG THE EAST COAST OF THE CASPIAN SEA

(A Preliminary Report)

Abstract

Benthic diatom flora on the eastern shores of the Caspian Sea is relatively poor: 126 species and their variations were found. Almost all of them belong to the class Pennatae. There were recorded six ecological groups according to water salinity. It is quite possible that Cocconeis scutellum var. adjuncta, Licmophora gracillis, and L. hastata penetrated into the Caspian Sea during the last decade, after the opening of the Volga-Don Canal.

The flora of diatom fouling has been investigated in a sufficient detail only along the west coast of the Caspian Sea (Grunow, 1878; Karayeva, 1961). Some information on the benthic diatoms (in a broad sense) of the east coast of the sea is found in a study by Grunow (1878), who investigated marine fouling in Krasnovodsk and Baku. The author lists 19 forms of diatom algae for the Krasnovodsk area, pointing out the size of only a few of the algae. Preliminary data on diatom fouling in the Caspian Sea are found in studies devoted to the investigation of phytoplankton (Genkel', 1909; Kiselev, 1938, 1940) and partly of benthos (Bening, 1937). This information is limited to the listings of bottom algae found in samples. In addition, they pertain to a degree to the dry northeastern gulfs.

This study presents a preliminary investigation of systematic composition of diatoms found in marine fouling along the west coast of the Caspian Sea, their ecological and biogeographical characterization, distribution along the coast, and with depth.

For this study, G. B. Zevina, a scientist at the Institute of Oceanology of the Academy of Sciences of USSR, kindly allowed me to use the diatoms collected along the east coast of the Caspian Sea during 1953-1961. Besides, I utilized my collections obtained from Krasnovodskiy zaliv in October 1961. The points where the material has been obtained are listed in Table 1.

The flora of benthic diatoms along the east coast of the Caspian Sea is not rich: I identified only 126 species and their variations belonging to 26 genera. All of them belong to the class of Pennatae, except for two variations of Melosira moniliformis belonging to the class of Centricae. As to the amount of species and individuals, the representatives of suborder Araphinales (mainly genera Grammatophora and Synedra) and suborder Monoraphineae predominate. All of the diatoms are, as a rule, colonial and sedentary forms adhering to natural objects (stones, cliffs, shells, algae) and artificial structures (piers, buoys, panels). Also the representatives of family Naviculaceae of suborder Biraphineae are numerous in marine fouling. These are singular forms moving freely among the foulers. Of the representatives of family Nitzschiaceae, Nitzschia sigmaformis var. socialis is constantly found in fouling, while the greater part of representatives of this family, as well as those of the family Surirellaceae, are bottom forms, but they are often brought onto the fouling as a result of roiling and continue to vegetate there, wherefore they are included in the general list of diatom fouling.

The analysis of diatoms made it possible to assign the collected /38
species to five ecological groups differing on the basis of their relation to the salinity of water (Table 2).

The brackish water and brackish water-marine forms of diatoms prevail in the Caspian Sea, both along the west (Karayeva, 1961) and along the east coast.

Only two typical marine forms of microphytobenthos are found in the Caspian Sea — Grammatophora and Licmophora. The brackish-fresh water and indifferent diatoms are represented by far smaller numbers of forms in the Caspian Sea.

After the opening of the Volga-Don Canal one could expect the transplantation of several euryhaline forms from the Black and Azov Seas into the Caspian Sea. In this way, evidently, the following diatoms entered the Caspian Sea: Cocconeis scutellum var. adjuncta, Licmophora gracilis, L. hastata Mer. (the latter was found only along the west coast). These species are not mentioned in the earlier literature on the Caspian Sea. Neither did I find them when processing the materials on diatoms of the western part of the sea, which were collected prior to 1953 (Karayeva, 1961). A complete and final processing of all the material that is at our disposal will permit the elucidation of the ways by which these forms immigrated into the Caspian Sea, and the number of new immigrants.

Table 1

The Distribution of Benthic Diatom Algae Along the East Coast of the Caspian Sea and Their Ecological Characterization *

Numerical sequence	Algae	Collection Points: ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogas-Gol	z. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	Ecology
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Melosira moniliformis var. subglobosa Grun.	+	+	+			+	+	+		+	+		+	+	+	М-С
2	M. moniliformis var. octogona Grun.	+		+				+	+			+		+	+		М-С
3	Grammatophora marina (Lyngb.) Kütz. var. marina		+		+		+				+	+					М-С
4	Gr. marina var. adriatica Grun.		+		+	+			+	+	+						М-С
5	Gr. oceanica (Eh Grun. var. oceanica		+	+	+	+	+	+	+	+	+	+			+		М-С
6	Gr. oceanica var. macilenta (W. Sm.) Grun.			+				+	+		+	+					М-С
7	Licmophora gracilis (Ehr.) Grun. var. gracilis						+					+					М
8	Diatoma vulgare var. lineare Grun.		+		+	+			+	+	+			+	+	+	П
9	D. vulgare var. breve Grun.				+	+											П
10	Fragillaria construens var. venter (Ehr.) Grun.										+						П
11	Synedra ulna (Nitzsch.) Ehr. var. ulna										+						П
12	S. tabulata (Ag.) Kütz. var. tabulata		+	+					+		+	+					М-С
13	S. tabulata var. acuminata Grun.			+	+												М-С

* M — marine; M-C — marine-brackish water; C — brackish water; C-П — brackish water-fresh water; И — indifferent (Euryhaline).

Table 1 (cont.)

Numerical sequence	Algae	Collection Points															
		ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	z. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	Ecology
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
14	S. tabulata var. obtusa Pant.		+														м
15	S. tabulata var. fasciculata (Kütz.) Grun.		+			+		+	+	+				+	+	+	м-с
16	S. tabulata var. intermedia Grun. . . .		+				+	+	+	+					+	+	м-с
17	S. tabulata var. parva (Kütz.) Grun.										+					+	м-с
18	Cocconeis scutellum Ehr. var. scutellum		+							+	+						м
19	C. scutellum var. adjuncta Perag. . . .						+		+								м
20	C. distans Greg. . .				+						+						м
21	C. placentula var. lineata (Ehr.) Cl. . .										+						п
22	C. placentula var. euglypta (Ehr.) Cl.			+				+	+		+	+			+		п
23	C. pediculus Ehr. var. pediculus . . .		+		+			+		+	+						с-п
24	C. pediculus f. abruptus O. Korotk. .		+														с
25	C. quarnerensis Grun.							+			+						м
26	Achnanthes delicatula (Kütz.) Grun. var. delicatula . . .				+	+					+			+			с-п
27	A. brevipes Ag. var. brevipes			+	+							+			+		м-с
28	A. brevipes var. intermedia (Kütz.) Cl.			+	+		+	+	+		+	+			+		м-с
29	A. brevipes var. parvula (Kütz.) Cl. .			+	+				+			+					м-с
30	A. longipes Ag. . .										+	+		+	+		м

Table 1 (cont.)

Numerical sequence	Algae	Collection Points															Ecology
		ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	z. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
31	Rhoicosphenia curvata (Kütz) Grun. var. curvata	+	+		+	+	+	+	+	+	+	+			+		с-п
32	Mastogloia angulata Lewis.										+	+					м
33	M. elliptica (Ag.) Cl. var. elliptica . .							+			+						с
34	M. smithii Thw. var. smithii		+								+	+					с-п
35	M. smithii var. lacustris Grun.	+	+					+				+			+		с-п
36	M. braunii Grun. .								+			+					с
37	M. pusilla (Grun.) Cl.	+	+				+	+		+	+	+	+		+		м-с
38	M. pusilla Grun. var. pusilla	+	+					+				+			+	+	м-с
39	M. baltica Grun. .		+														с
40	M. labuensis Cl. .		+														м
41	Diploneis gorjanovicii (Pant.) Hust. .		+					+	+		+						с
42	Diploneis suborbicularis (Donk.) Cl. .											+					м
43	D. smithii (Breb.) Cl. var. smithii . . .		+									+		+			м-с
44	D. smithii var. pumila (Grun.) Hust. .										+				+		с
45	D. fusca (Greg.) Cl.							+			+						м
46	D. ovalis var. oblongella (Naeg.) Cl. .		+	+				+	+		+						м
47	D. didyma (Ehr.) Cl.		+	+					+		+	+		+			м-с
48	D. dombilittensis (Grun.) Cl. var. dombilittensis							+			+						с-п

Table 1 (cont.)

Numerical sequence	Algae	Collection Points															Ecology
		ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	z. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
49	D. dombilittensis var. subconstricta A. Cl.											+					с-п
50	D. elliptica (Kütz.) Cl. var. elliptica . .								+								и
51	D. bombus Ehr. var. bombus		+	+	+	+	+	+	+	+	+	+					м
52	Amphipleura rutilans (Trentep.) Cl. . .		+	+	+	+			+		+	+	+		+	+	с
53	Brebissonia boeckii Ehr.			+													с
54	Stauroneis phoenicenteron Ehr. var. phoenicenteron . . .			+					+			+					с-п
55	Navicula gregarea Donk.								+		+						с
56	N. spicula Hickie											+					м
57	N. scopulorum Bréb.		+		+		+		+	+	+	+	+	+	+	+	м-с
58	N. cryptocephala Kütz. var. cryptocephala										+						с-п
59	N. cryptocephala var. veneta (Kütz.) Grun.								+								с-п
60	N. cryptocephala var.?			+			+		+			+					с?
61	N. cincta (Ehr.) Kütz. var. cincta . .										+						с-п
62	N. gracilis Ehr. .						+										п
63	N. menisculus Schum. var. menisculus	+															с-п

Table 1 (cont.)

Numerical sequence	Algae	ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	s. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	Ecology
		Collection Points															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
64	N. tuscula (Ehr.) Grun. var. tuscula .							+	+		+						м
65	N. salinarum Grun. var. salinarum . . .											+					с
66	N. digitoradiata (Greg.) A. S. var. digitoradiata											+					м-с
67	N. gastrum Ehr. var. gastrum	+															м
68	N. lanceolata (Ag.) Kütz var. lanceolata								+			+					м
69	N. ramosissima f. caspia Grun.		+	+	+				+	+	+						с
70	N. humerosa Bréb. vas. humerosa . . .							+			+						м-с
71	N. latissima Greg. var. latissima . . .		+						+		+						м
72	N. creucburgensis Krasske								+		+						с
73	N. intricata Kar.										+	+					с
74	N. pennata var. pontica Mer.								+		+						с
75	N. pygmaea Kütz.			+							+	+		+			с
76	N. forcipata Grev. var. forcipata . . .							+									м
77	Caloneis formosa var. holmiensis Cl.											+		+			с
78	C. amphisbaena (Bory) Cl. var. amphisbaena								+								с
79	C. amphisbaena var. subsalina (Donk.) Cl.			+					+								с

Table 1 (cont.)

Numerical sequence	Algae	Collection Points															
		ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	s. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	Ecology
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
80	C. schumaniana (Zakr.)var. biconstricta f. lamella Zabelina											+					м
81	Gyrosigma attenuatum (Kütz.) Rabh.								+		+	+			+		м
82	G. spencerii (W. Sm.) Cl. var. spencerii								+			+					с
83	Pleurosigma delicatulum W. Sm. . .		+														м-с
84	P. angulatum (Queck.) W. Sm. var. angulatum								+		+	+					м-с
85	Tropidoneis lepidoptera (Greg.) Cl var. lepidoptera . .										+	+					м
86	Amphora marina (W. Sm.) V. H. . . .											+					м
87	A. robusta Greg.								+		+						м
88	A. ovalis Kütz. var. ovalis										+						м
89	A. ovalis var. pediculus Kütz								+			+					м
90	A. mexicana var. major A. Cl.								+			+					м
91	A. holsatica Hust. var. holsatica . . .				+				+		+	+					с
92	A. holsatica var. tenera Kar.			+							+						с
93	A. coffeaformis Ag var. coffeaformis . .			+					+								м-с
94	A. lineolata Ebr										+	+					с
95	A. angusta (Greg.) Cl. var. angusta . .		+	+					+								м-с

Table 1 (cont.)

Numerical sequence	Algae	ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	z. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	Ecology
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
96	A. staurophora Dannf.											+					c
97	Epithemia sorex Kütz. var. sorex . .		+				+			+	+						c-п
98	Rhopalodia gibba var. ventricosa (Ehr.) Grun.	+	+	+	+	+	+	+	+	+	+		+	+			м
99	R. musculus (Kütz.) O. Müll. var. musculus		+		+	+					+	+		+			м-с
100	R. musculus var. succincta (Bréb.) Perag.		+	+			+	+			+	+					c
101	Hantzschia virgata (Roper) Grun. var. virgata										+						c
102	Nitzschia triblionella var. maxima Grun.											+					c-п
103	N. granulata Grun. var. granulata . . .				+									+			м
104	N. punctata (W. Sm.) Grun. var. punctata		+		+						+	+		+			[illegible]
105	N. punctata var. aralensis Borscow . .											+					c
106	N. punctata var. coarctata Grun. . . .						+										c
107	N. punctata var. minutissima Poretzky										+						c
108	N. hungarica Grun. var. hungarica . . .											+					c
109	N. acuminata (W. Sm.) Grun.			+								+					c

Table 1 (cont.)

Numerical sequence	Algae	Collection Points															
		ostrov Kulaly	zaliv Sarytash	Bautino	mys Melovoy	mys Peschanyy	z. Aleksandr-Bay	zaliv Kenderli	mys Bekdash	ostrov Kara-Ada	p. Kara-Bogaz-Gol	z. Krasnovodskiy	banka Livanova	o. Ogurchinskiy	banka Ul'skogo	Zelenyy bugor	Ecology
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
110	N. apiculata (Greg.) Grun.			+	+	+			+		+	+		+			c
111	N. circumsuta (Bail.) Grun.											+					c
112	N. hybrida Grun.							+									c
113	N. lanceolata f. minima V. H. . . .	+			+			+	+								c
114	N. sigm: (Kütz.) W. Sm. var sigma .					+			+		+						c-n
115	N. sigma var. rigidula Grun.											+					c-n
116	N. sigmaformis var. socialis Kar.			+													c
117	N. laevi Kar. . .				+					+	+		+	+			c
118	N. obtusa W. Sm. var. obtusa											+					c
119	Surirella ovata Kütz var. ovata . .		+														■
120	S. ovata var. subsalina (W. Sm.) Hust						+		+								c
121	S. striatula Turp.			+								+					c
122	Campylodiscus clypeus Ehr. var. clypeus											+					c
123	C. clypeus var. bicostatus (W. Sm.) .											+					c
124	C. aralensis I. Kiss.											+		+			c
125	C. echeneis Ehr. .		+						+		+	+		+			c
126	C. daemelianus Grun.										+	+					c

Table 2

Relationship Between the Numbers of Species of Benthic Diatoms Belonging to Various Ecological Groups Responsible for Marine Fouling Along the East Coast of the Caspian Sea

Ecological Group	Number of Forms	
	Absol.	%
Marine.	20	16
Brackish water-marine	27	21
Brackish water.	48	39
Brackish-fresh water.	14	11
Indifferent (euryhaline).	17	13

A biogeographical analysis of benthic diatoms growing along the east coast demonstrated that cosmopolitan forms dominate, constituting about 35°/₀ of the total number of forms. The following forms are most widely distributed: Synedra tabulata var. tabulata, Amphipleura rutilans, Navicula pygmea, etc. These are followed by boreal forms which constitute about 25°/₀ of the total number of diatoms. The boreal forms include Grammatophora oceanica var. oceania, Amphora holsatica var. holsatica, etc. The number of warm water diatoms found in marine fouling is considerably smaller; these forms inhabit the southern parts of boreal regions or subtropical regions. They make up 10°/₀ of the total number of diatoms and are represented by Mastogloia angulata, Cocconeis scutellum var. adjuncta, etc. Lastly, the Caspian Sea is inhabited by forms living in any type of water basin and in all geographical zones, and are ubiquitious. They constitute 6°/₀ of all the forms and are represented by Rhoicosphenia curvata, Nitzschia sigma var. sigma, etc. Rh. curvata is very widely distributed along the east coast of the Caspian Sea. The Arctic diatoms are represented in the fouling along the east coast only by one species — Navicula spicula. We cannot yet surely assign a considerable number of diatoms constituting the marine fouling to one or the other group, because their geographical distribution has not been sufficiently investigated.

Some of the species found in the Caspian Sea seldom are observed in other water basins and their distribution is limited. Among them we have Cocconeis scutellum var. adjuncta, Navicula creuzburgensis, N. ramosissima f. caspia, Amphora staurophora, Rhopalodia musculus var.

succincta. The Diploneis gorjanovicii, which inhabits the eastern coastal belt of the sea was up to the present time known only as a fossil species.

The diatom algae are found as foulers in the Caspian Sea from the intertidal zone to a depth of 10-15 m. However, their main mass is limited to the intertidal zone and below it to a depth of 5-6 m. The investigation of vertical distribution of diatoms in marine fouling along the east coast of the Caspian Sea made it possible to clarify the vertical zoning and distribution of foulers in connection with various living conditions in each of the zones.

The first zone includes the surf zone, extending to a depth of 0.5-1 m. This zone is characterized by a constant mechanical action of waves, by abrupt fluctuations of temperature, by abundance of light and by periodic drying. The diatoms of this zone are represented by single and colonial forms, which are firmly attached to objects with the aid of mucus. Altogether 44 species and variations of diatoms were observed in this zone. Their systematic composition is very specific. Single forms belong to the family Achnanthaceae, while the colonial, as well as the single, forms belong to the family Naviculaceae. The forms whose colonies appear as slimy tubules dominate, as for instance, Amphipleura rutilans, Navicula ramosissima f. caspia, etc.; among single forms, the following species dominate: Cocconeis placentula var. euglypta, Mastogloia pumila, M. smithii var. lacustris.

In the second zone, extending from a depth of 0.5-1 m to 10-15 m, the living conditions are quite different: the belt is never dry, the mechanical impact of water is smaller, the amount of light decreases, and the fluctuations of temperature are milder. Here one can find attached colonial forms. The character of colonies in this zone differs sharply from that of the first zone. Chain and bush-shaped colonies predominate in the second zone. Altogether, 52 species and variations of diatom algae have been observed in this zone, the prevalent species being Grammatophora oceanica var. oceanica, Gr. marina var. marina, variations of Synedra tabulata, as well as Rhoicosphenia curvata, etc. A large number of motile diatoms are found among the foulers, such as Navicula gregarea, variations N. cryptocephala and Diploneis didyma, Campylodiscus aralensis, etc. The number of diatoms is great in both of the zones. Even the filamentous blue-green algae, which in the Barents and Black Seas are covered thinly by diatoms, are found in large quantities in the Caspian Sea.

My conclusion concerning the diatoms of the west coast belt - namely, that the selective ability with respect to various objects is not clearly pronounced in the Caspian Sea - is also confirmed by investigations of their distribution along the east coast. The decisive factors for the species composition of diatoms in marine fouling are salinity, depth, and temperature.

A comparison between the species composition of diatoms in marine fouling along the east and west coasts (Karayeva, 1961) demonstrated a considerable similarity. Of 126 diatoms found along the east coast, 11[illegible] were common with the forms of the west coast, i.e. almost 93°/o. Representatives of three genera not represented along the west coast (Brebissonia, Stauroneis and Hantzschia) were observed along the east coast. Many of the genera inhabiting the estuary area of the Volga were not found along the east coast. This is understandable because in this part of the sea the salinity (0-10°/oo) differs considerably from the salinity of water along the east coast (13-14°/oo).

The complex of dominant species of diatoms in marine fouling along both of the coasts is similar. However, some of the species, which appear to dominate along the west coast, were either not found along the east coast or occurred only singly (Nitzschia filiformis, Cocconeis pediculus, C. abruptus, Diploneis smithii var. smithii). But Synedra tabulata var. acuminata, Cocconeis quarnerensis, Navicula intricata, were found singly along the west coast and in considerable quantities along the east coast.

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K. S. Arbuzova

MARINE FOULING IN THE SOUTHEASTERN PART OF THE BALTIC SEA

(Preliminary Report)

Abstract

Samples of fouling on buoys and spar buoys placed in the Soviet waters of the southeastern part of the Baltic Sea (from Kronschtadt to Baltiysk) were collected during 1960-1961. 44 buoys and 6 spar buoys were tested, most of which stayed in the sea during seven to eight months, including all the warm seasons. During this period we can observe the development of fouling from its first phase, (the phase of settlement on a free surface) to the phase, when its development is stopped by the cold winter temperature of water and is then destroyed by man. These foulings do not reach the final phase of their development. The slow growth of mytilus in the Baltic Sea and a short period of its life (less than a year) is the reason for the above mentioned process.
The results of the research showed that the fouling in this part of the Baltic Sea was insignificant. The average biomass of fouling observed by us was 2.4 kg/m^2. This part of the Baltic can be divided into nine regions, which are classified by biomass and composition of fouling.

The study of marine fouling in the Baltic Sea (east of the Sound) has not yet been carried out (Tarasov, 1959, 1961). Only recently Poland published a comprehensive investigation by Biernacka (1961) in marine fouling in Gdynia-Orlovo. Fouling in the area lying west of the Sound has been investigated. For instance, Hentschel (1916) observed the seasonal character of marine fouling of Cordylophora caspia on experimental panels submerged in the Harbor of Hamburg, but Caspers (1952) published a detailed study in marine fouling on buoys at Helgoländer Bucht. In the Soviet waters of the Baltic Sea, the marine fouling has not yet been investigated. Meanwhile, the investigation of the phenomenon in the area is of great interest, the more so because systematic observations on the process and character of marine fouling are conducted in other seas of the Soviet Union.

In connection with it, in 1960 and at the beginning of 1961, I collected data of marine fouling on 44 buoys and 6 spar buoys, which were placed in the Soviet waters in the southeastern part of the Baltic Sea from Kronshtadt to Baltiysk. The samples were taken by a metal scraper from areas 0.01 m^2 in size, which were located, as a rule, along the water line of the buoys or spar buoys (0-20 cm) and at the depths of 2.4 and 6 meters. From four objects we took only qualitative samples, because the fouling on them was weakly developed.

The laboratory processing of the material was carried out by the usual method applied to collections of quantitative samples of benthos. The identification of plant and animal fouling was conducted by A. A. Zinova (algae), E. I. Androsova (bryozoans), D. V. Naumov (hydroids), and E. F. Gur'yanova (crustaceans) to whom I express my deep appreciation.

It need be noted that the greater part of the buoys and spar buoys were in the sea for the same length of time, which included the entire warm season of the year (from April-June 1960 to December 1960 and January 1961, i.e. 7 to 8 months). During this time, the marine fouling developed on them from its initial phase (the moment of occupation of the free surface) to the phase when the further development was stopped by low winter temperatures of water, or by artificial destruction caused by man. Thus, according to data by I. I. Nikolayev (1957), the appearance in the plankton of large quantities of larvae of species participating in the fouling occurs in June, i.e. after the laying of buoys in the sea. However, they are removed as a rule in the winter.

Thus, the brief period of existence of the fouling on buoys and spar buoys in the given water basin, did not give the foulers a chance to reach their final phase of development, which, for temperate latitudes, /42
is a continual cover of <u>Mytilus</u> (Scheer, 1945; Nikitin, 1947; Caspers, 1952; Rudyakova, 1958). However, the simultaneousness of laying and removal of buoys makes possible the comparison between the processes of formation of fouling in various areas of the Baltic Sea.

The following 10 species of plants (except for diatoms) and 10 species of animals were observed on the buoys placed in the southeastern part of the Baltic Sea:

1. Diatom Algae

2. Green Algae:

Enteromorpha crinita (Roth) j. Ay.
Cladophora rupestris (L.) Kütz

1. Hydroids:

Cordylophora caspia (Pallas)
Obelia loveni (Allm.)
Hydroidea sp. (Perigonimus megas Kinne?)

Cladophora glomerata (L.) Kütz.

3. Red Algae:

Ceramium cibricum N. Petersen
Ceramium rubrum (Huds) Agardh.
Porphyra atropurpurea De Toni

4. Brown Algae:

Ectocarpus siliculosus (Dillw) Kuck
Ectocarpus siliculosus f. varians Kuck
Ectocarpus confervoides (Roth) Le Jol.
Sphacelaria arctica Harvey

2. Bryozoans:

Electra crustulenta v. baltica Borg.

3. Mollusks:

Limnea stagnalis (L.)
Mytilus edulis (L.)

4. Crustaceans:

Balanus improvisus Darwin

5. Amphipods:

Gammarus salinus Spoon
Caliopius crenatus Chevreux

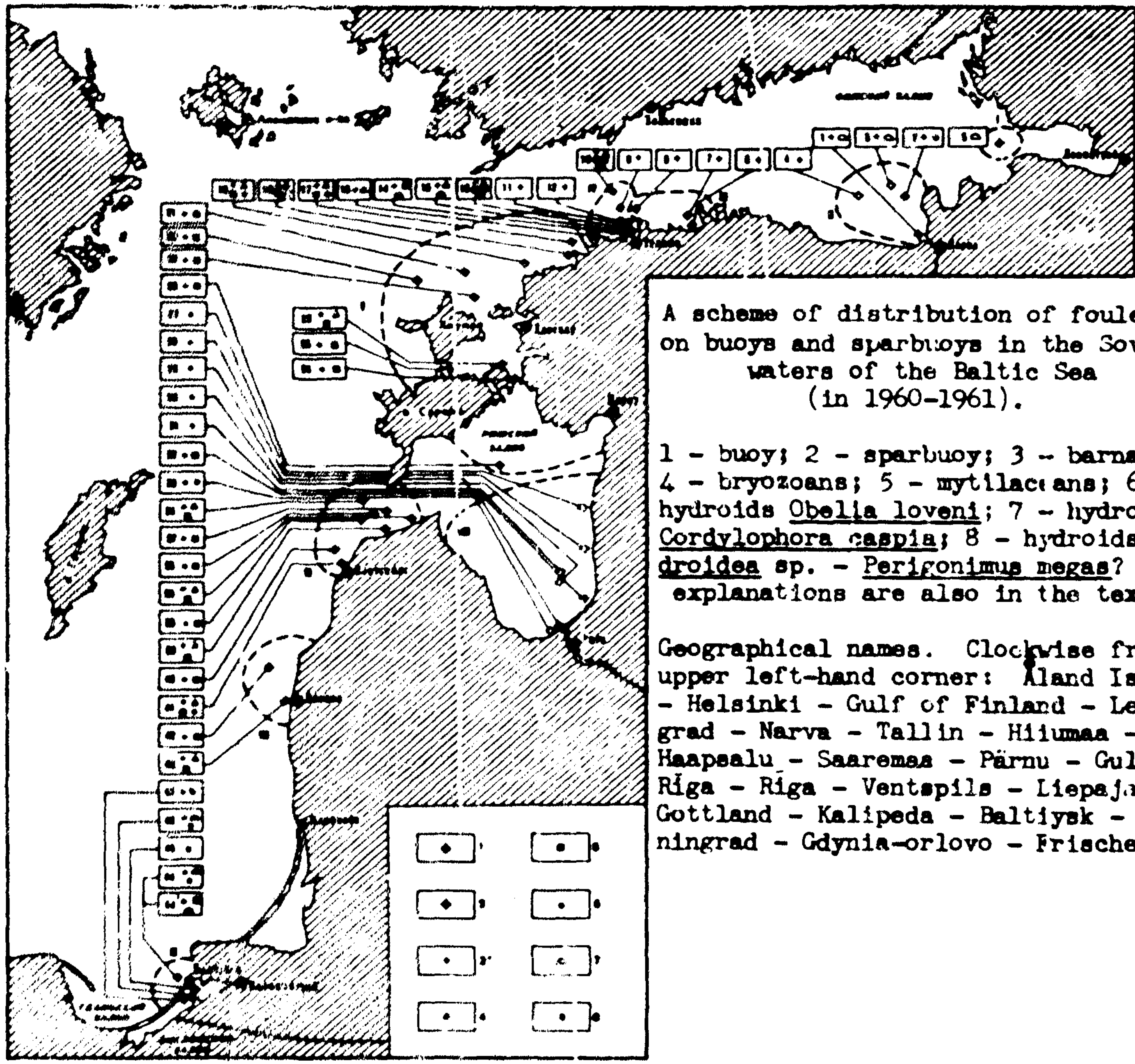
6. Isopods:

Idothea baltica (Pallas)

The main and mass forms are the following: diatoms and one species of green algae (Cladophora rupestris), two species of animals; namely, barnacles and mytilaceans. One more species can be assigned to the group, namely, Cordylophora caspia, which forms the principal base for foulers on buoys in Frisches Haff (Vislinskiy zaliv) and yields the greatest quantity of biomass for the Baltic Sea, namely, 1[illegible].150.0 g/m^2 (buoy No. 4[illegible]).

It is generally known that the species composition of the fauna of foulers is always poorer than that of the species composition of the benthic fauna because entire groups of animals, such as mollusks, worms, some of the crustaceans, and others which live in the bottom, cannot participate in marine fouling. This is also true of the Baltic Sea; the following numbers confirm the statement: only 9-10 species of animals were observed among the foulers, while the composition of the benthos includes 36 species in the Pärnu laht (Yarvekyul'g, 1960) and 41 species in the central part of the Baltic (Shurin, 1953). It is also seen from the data that the benthic fauna of the Baltic is relatively poor, which may be the result of a low salinity of the sea and a complex geological history (Zenkevich, 1947).

Therefore, if the fouling of the Baltic Sea is compared with that of the Black, Caspian, White, and Barents Seas, or with that of the far



A scheme of distribution of foulers on buoys and sparbuoys in the Soviet waters of the Baltic Sea (in 1960-1961).

1 - buoy; 2 - sparbuoy; 3 - barnacles; 4 - bryozoans; 5 - mytilaceans; 6 - hydroids <u>Obelia loveni</u>; 7 - hydroids <u>Cordylophora caspia</u>; 8 - hydroids <u>Hydroidea</u> sp. - <u>Perigonimus megas</u>? The explanations are also in the text.

Geographical names. Clockwise from upper left-hand corner: Åland Islands - Helsinki - Gulf of Finland - Leningrad - Narva - Tallin - Hiiumaa - Haapsalu - Saaremaa - Pärnu - Gulf of Riga - Riga - Ventspils - Liepaja - Gottland - Kalipeda - Baltiysk - Kaliningrad - Gdynia-orlovo - Frischen Haff.

eastern seas, in which the salinity of water is higher and bottom fauna is many times richer, the fouling fauna of the Baltic Sea is naturally poorer. According to data by N. A. Rudyakova (1958), 63 species of animals are found in far eastern seas, 15 of which are the basic mass forms. G. B. Zevina (see this compilation of papers) points out 20 species of foulers for buoys, of which 8 species constitute the main mass. For the Caspian Sea, Zevina points out 11 main species of 48 participating in fouling, the mean biomass being 7-11 kg/m^2 in the northern Caspian sector during seven months and 22.5 kg/m^2 in Krasnovodskiy zaliv during seventeen months (Zevina, 1962). In the Black Sea, the biomass of foulers may reach 28.0 kg/m^2 in one warm season (Nikitin, 1947). The mean mass of foulers for the Soviet waters of the Baltic Sea is 2411 g/m^2. This value of biomass is based on investigations of one year only, 1960.

The temporary increase of salinity, which has been observed periodically during the last decade in the Baltic Sea, is associated with intense cyclonic activity over the North Atlantic Ocean and the northwestern sector of Europe, as well as with fluctuations in the influx of waters with high salinity through the Sound; this phenomenon involves mainly the deep zones of the sea - namely, the Bornholm and Gdynia depressions, and the central and northern sections of the sea. However, in the surface layer, especially in the southeastern part of the sea, no noticeable variations in hydrological and hydrochemical conditions have been observed (Soskin and Chernovskaya, 1961). One may think also that the fauna of foulers has developed without substantial changes in species composition and quantity during the recent years (to 1961).

On the basis of the character of marine fouling, the given region of the Baltic Sea can be divided into several areas (see the scheme and table).

Area I - eastern part of the Gulf of Finland (area of ostrov Kotlin). This area is characterized by a low salinity, 0.5 to 1°/oo, and with corresponding fresh- and brackish-water fauna and flora. Buoy No. 5 was here (near Kronshtadt). Fouling on it was weak consisting mainly of green (Cladophora rupestris) and diatom algae, occupying the belt from 0-2 m. At the depth of 2-3 m one could observe scattered colonies of hydroids (Cordylophora caspia). On a ballast ring, a single Limnea stagnalis was found. The marine fouling consisting of random spots covers only part of the surface of the buoy, although it was in the water from May to November 1961. A similar fouling was described by Caspers (1954) for the area of the Elbe estuary, where fresh water forms prevail and the influence of the sea is weakly pronounced.

Area II - Narva laht. The salinity in 1960 was 2.27°/oo. Two buoys (No. 1 and 2) and two spar buoys (No. 3 and 4) were examined. Qualitative samples were taken; quantitative samples were taken only from buoy No. 2. Here the fouling also was weakly pronounced; however, its composition was somewhat different: in addition to the brackish water fauna, one could observe marine fauna (Balanus improvisus, Obelia loveni, etc.). The distribution of organisms over the surface of the buoys and spar buoys was rather clearly pronounced. From the surface of the water to a depth of 1 m, only algae were found (diatom and green algae - Cladophora ruspestris). At a depth of 2-3 m, scattered filaments of hydroids were found (Cordylophora caspia and Obelia loveni, the latter only on buoy No. 2). Among the hydroids and a little below them (to a depth of 4 m), scattered shells of small barnacles were found (about 100-150 specimens over the entire surface of the buoy). The mean biomass of fouling on buoy No. 2 was 134.5 g/m^2.

Areas III and IV constitute a natural continuation of Area II. They include the following gulfs: Kolga laht, Tallinna Laht, Tallinomadal (T. bank), and islands: Prangli and Aegna to Surupi (cape). They are characterized by a constant increase of salinity (from east to west) to 6°/oo and the increase of temperature of water to 6.16°, as well as by a decrease of days with ice. These conditions correspond to a gradual complication of fouling biocoenosis. The fouling is supplemented by such new species as the bryozoan Electra crustulenta var. baltica, mytilaceans, and green alga Enteromorpha glomerata; at places a complex stratification of organisms is created, which leads to competition for space and food.

Barnacles constituted the main organisms on these buoys. Their quantity per unit surface, as well as their size, increases gradually. /45 Thus, on buoy No. 6 in Area III (Kolga laht) the biomass of barnacles was ten times smaller than on buoy No. 14 in Area IV (Tallinna laht). If the size of barnacles in Area III fluctuates from 0.2 to 0.5 cm, then in Area IV barnacles are from 0.2 to 1.1 cm. Individual scattered populations of foulers on buoys expand, forming a continuous cover blanketing uniformly the entire underwater surface of the buoys. Although the fouling in these areas continues to remain basically a one-layer cover, sometimes the colonies of bryozoans blanket the shells of barnacles with a dense cover. But when they develop directly on the metal surface of a buoy, roundish cake-shaped colonies reaching 2 cm in diameter are formed.

Distribution of Marine Fouling on Buoys and Sparbuoys in the Soviet Waters of the Baltic Sea (1960–1962)
(the numbers correspond to the numbers of the figure) *

No. of buoys and spar-buoys	Biomass of foulers, g/m²					
	Barn-acles	Bryo-zoans	Myti-laceans	Hydroids		
				Obelia loveni	Cordylophora caspia	Hydroids
1	+	—	—	—	+	—
2	132,0	—	—	2,5	—	—
3	+	—	—	—	+	—
4	+	—	—	—	+	—
5	—	—	—	—	+	—
6	175,0	—	—	—	—	—
7	285,0	—	—	—	—	—
8	343,0	—	—	—	—	—
9	508,0	—	—	—	—	—
10	608,0	0,4	0,25	0,5	4,2	—
11	652,0	—	—	—	—	—
12	658,0	—	—	—	—	—
13	1798,3	43,23	29,17	15,0	0,1	—
14	695,0	—	2,0	—	28,9	—
15	1113,5	0,15	—	—	0,1	—
16	742,0	0,3	—	—	—	—
17	2044,0	41 2	43,8	102,7	—	—
18	1517,25	6,0	0,85	80,85	10,0	—
19	1133,5	3,6	1,8	12,5	—	—
20	920,0	—	6,2	—	—	—
21	1040,0	—	10,0	—	—	—
22	1127,6	—	66,0	—	—	—
23	2225,0	1,2	4,2	—	—	—
24	1590,0	—	7 5	—	—	—
25	1512,0	—	11,8	—	—	—
26	3149,5	—	0,1	—	—	—
27	2655,0	—	—	—	—	—
28	3150,0	—	—	—	—	—
29	13200,0	—	—	—	—	—
30	1670,0	—	—	—	—	—
31	50,0	—	—	—	—	—
32	4776,5	—	16,5	—	—	—
33	2646,0	—	—	332,5	—	—
34	2644,7	4,17	290,8	—	—	—
35	1258,3	—	48,03	—	—	—
36	2276,5	—	17,5	—	—	—
37	1516,0	—	1,2	—	—	—
38	2187.3	2,07	162,03	—	—	—
39	2158,3	0,67	213,3	—	—	—
40	1454,3	—	178,03	—	—	—
41	883,3	4,33	312,2	250,0	—	—
42	6182,5	—	8,85	—	—	—
43	1219,5	1,85	17,4	—	—	—
44	646,0	—	—	—	+	1920,0
45	—	—	—	—	—	7850,0

Table (continued)

No. of buoys and spar-buoys	Biomass of foulers, g/m^2					
	Barn-acles	Bryo-zoans	Myti-laceans	Hydroids		
				Obelia loveni	*Cordylophora caspia*	Hydroids
46	1380,0	—	—	—	592,0	+
47	957,0	—	—	—	—	920,0
44	539,3	—	13,30	—	597,4	—

* Plus denotes the presence on buoys and spar buoys of foulers, the quantity of which was not established.

The distribution of foulers along the vertical on buoys is not uniform. Merely a belt of algae to a depth of 1 m can be discerned.

The mean biomass of fouling on buoys No. 6-8 in Area III, where only barnacles and algae (diatoms and Cladophora) were found, constituted 279.4 g/m^2. In Area IV, where buoys No. 9 to 16 had been anchored, the mean biomass of fouling reached 883.6 g/m^2.

A small quantity of mytilaceans was found on buoys No. 1[illegible], 13, and 14. They were very small (to 0.[illegible] cm), the average quantity being only [illegible],114 ind/m^2. Therefore mollusks cannot exercise appreciable influence on barnacles, bryozoans and hydroids, which had occupied the buoys before.

Area V constituted the large neck of the Gulf of Finland, Estonian Islands (Hiiumaa and Saaremaa), Strait Muhu Väin and the northeastern part of the Gulf of Riga. The area is characterized by intense water exchange, a mean salinity of 6.49‰, and water temperature of [illegible]° C, by a large quantity of plankton, and a considerable influx of suspended organic matter from surrounding land masses (Zenkevich, 1947; Yarvekyul'g, 196[illegible]). Buoys numbered 1[illegible] to [illegible] were in the area. The mean biomass of marine fouling constituted [illegible].[illegible] g/m^2. The main foulers were barnacles and mytilaceans, the accompanying forms being bryozoans, two species of hydroids (Cordylophora caspia and Obelia loveni) and various algae (diatoms, green, brown, and red algae).

The barnacles formed two lower layers of the fouling. Mytilaceans were found on barnacles, constituting a mass component of fouling on all the buoys of this area; the quantity of bryozoans and hydroids was smaller. The size of the barnacles was diverse (from 0.4 to 1.5 cm). Most frequently, barnacles were found from 0.6 to 1.0 cm long, which is the mean size. The barnacles prevail over all the other foulers, making up the main biomass. Thus, their mean biomass on buoys equaled 2673.5 g/m^2, the mean numerical value being 10,967 ind/m^2. The greatest numbers of barnacles were found on buoy No. 18 - namely, 25,800 ind/m^2.

Mytilaceans occupied all the less protected spots between the shells of barnacles and were sticking to their lateral walls. Their numbers were considerable, reaching 11,600 ind/m^2. Their size was, however, very small (mainly to 0.3 cm; a few reaching 0.6 cm). The mean biomass was 19.2 g/m^2.

The late settlement and slow development of mytilaceans in the given sector of the sea, as well as the limited period of observations, did not permit the reaching of a durable and stable state of settlement (climax), as it was pointed out above.

The character of marine fouling in Area VI was very similar to that of the preceding area. It includes the access to the part of Ventspils and Irbeni väin (Irves saurums) (buoys No. 34 to 41). It can be assumed that the given area located near the entrance to the Gulf of Riga, i.e. in the zone characterized by intensified water circulation and influx of a large quantity of organic matter from the gulf, is rich in plankton and detritus. This creates favorable conditions for the development of marine fouling, the more so for the reason that the dilution, which is observed in the interior of the Gulf of Riga, is not pronounced in this area.

The main foulers are the same as in Area V; however, the barnacles are in the majority; then follow bryozoans, hydroids Obelia loveni, amphipods and various algae (on buoys that are not soiled with petroleum). The mean biomass of the area is 2030.3 g/m^2. The mean biomass of barnacles constitutes 1797.3 g/m^2, the maximum being 4072.0 g/m^2 and 18,900 ind/m^2 (at the depth of 4 m, buoy No. 34). The mean biomass of mytilaceans on the buoys was 175.4 g/m^2, the maximum being 1335.0 g/m^2 and 295,000 ind/m^2 (at the depth of 3 m, buoy No. 41). The size of mytilaceans fluctuates from 0.05 to 1.3 cm. However, more often mollusks were found with sizes varying from 0.3 to 0.6 cm. All of the organisms form two layers. Barnacles, which form the entire first layer and also part of the second layer, reach great numbers (to 21,800 ind/m^2), which leads to the elongation of the shell. Numerous mollusks find shelter among the shells. Bryozoans grow either on barnacles or on mytilaceans; however, their numbers are insignificant and they do not reach great sizes. The main mass of hydroids is found at the depth of 1.5-2 m from the surface. The development of mytilaceans among hydroids is, as a rule, weakly pronounced. If there are no hydroids on a buoy, the mollusks occupy the entire surface of the buoy, forming spots of accumulations in the most diverse places.

As to the amphipods, such as Gammarus salinus and Calliopius crenalatus, their number on buoys in this area was considerable (from 100 to 1000 ind/m^2); besides, they are uniformly distributed with depth.

Almost all the species of algae that were mentioned above are represented in this area. The only exception is Porphyra atropurpurea, which is found only in Frisches Haff (Visla estuary). The distribution of algae on buoys follows the general pattern. With the absence of pollution, diatoms and green algae form a belt along the water line. They are joined by small numbers of brown and even red algae, which are associated with increased turbidity of water or with large quantities of foulers and shaded places, furthering the growth of the algae. At the depth of 2-6 m the green algae are less frequently found than red and brown algae. The quantity of red algae is insignificant on buoys.

The diatoms are, as a rule, distributed over the entire underwater /47
surface of the buoy, and they grow on free sections, as well as among other foulers.

The main type of fouling is also characteristic of Area VII (near Liepaja, on buoys No. 42, 43, 48, and 49). The basic organisms are the same as in Area VI; they are followed by bryozoans; the only crustacean is Idothea baltica; of algae we have diatoms, Ceramium cimbricum and Enteromorpha crinita. The distribution of these organisms over the surface of buoys does not differ from that in Area VI. However, the biomass of individual components of fouling, as well as the mean biomass, is in this area considerably smaller than in the two preceding areas. This can be explained by a relative impoverishment of plankton (Shurin, 1953), which constitutes the main source of food for foulers and which also supplies their larvae with food.

During the warm season of 1960, the mean biomass of marine fouling in Area VII reached about 1500 g/m^2. The greater part was made up by barnacles (1451.0 g/m^2). Barnacles of all sizes were observed here, the most frequent, and average, length being 0.6-1.0 cm. The length of mytilaceans varied from 0.1 to 0.6 cm, though small individuals with sizes ranging from 0.1 to 0.3 cm prevailed. The mean biomass for the area was 13.1 g/m^2. The maximum biomass of mytilaceans was found at the depth of 1.5 m from the surface on buoy No. 43, where the value reached 32.0 g/m^2 and the number was about 5500 ind/m^2.

It need be noted that no fouling was observed on buoys No. 48 and 49. The point is that these newly painted buoys were placed in the water only by the middle of October 1960, when the settling of foulers did not take place.

The Gulf of Riga is rather diluted (5-3‰) but rich in nutrient plankton (Zenkevich, 1947), which creates a peculiar pattern of fouling. The region is therefore singled out as Area VIII characterized by a great quantity of marine fouling (3023.75 g/m^2) and uniform species composition. The main foulers are barnacles. Mytilaceans (found only on buoy No. 32), the hydroid Obelia loveni (on buoy No. 33) and algae (mainly diatoms) appeared to be only accompanying forms and seldom were found, and in very small quantities.

The quantity of barnacles was very great on all the buoys and spar buoys (from No. 27 to 33), their numbers reaching 55,800 ind/m^2. The greatest number of barnacles was on spar buoy No. 29, which was in the water for a period of two years and housed approximately 120,000 ind/m^2, the biomass being 13,200.0 g/m^2. The barnacles formed two, and in certain cases, even three layers.

Their maximum biomass constituted 5948.0 g/m^2 (at the depth of 5 m on buoy No. 32). Meanwhile, the barnacles of Areas III and IV were usually forming spots on buoys, consisting most frequently of only one layer; whereas in the given area they formed a continual mass consisting of two and three layers. Thus, according to the species composition, quantity and characteristics of distribution over the surface of buoys or spar buoys, the latter area differs considerably from Areas III and IV, despite the fact that in the three areas the bulk of marine fouling was formed by barnacles.

Of the eight objects placed in the Gulf of Riga, only five (buoys No. 32 and 33 and spar buoys No. 27, 28, and 30) were in the water seven months, including the entire warm season of 1960. The mean biomass of barnacles made up 3014.75 g/m^2, the total biomass of fouling being 3023.75 g/m^2. Buoy No. 31 was anchored in the water only on 1 September and taken out on 24 December 1960. It was covered only by small single barnacles, scattered all over the surface of the buoy.

The buoy No. 50, which was anchored in the gulf on 15 September and taken out on 24 December 1960, was completely devoid of foulers. Hence, it follows that in the Gulf of Riga the settlement of larvae of barnacles is, as a rule, completed by the middle of September, which is evidently associated with abrupt cooling of water in the second half of September. /48

The last area, Area IX, covers Frisches Haff and the northeastern part of Gdynia-Orlovo in the area of Baltiysk. The samples of marine fouling were taken from buoys No. 44-47. Buoy No. 44 was in the sea west of Baltiysk from 8 August to 27 December, i.e. 4.5 months when the water was rather cold. Despite the fact that the occupation of the buoy by larvae could occur only during three months (to November) and that the temperature was gradually diminishing, the mean biomass of fouling was considerable on the buoy (2603.2 g/m^2), but the greatest value of the biomass of hydroids reached 5760.0 g/m^2. The main foulers were hydroids.

The remaining three buoys were anchored in the Frisches Haff for 8.5 months. The main foulers were hydroids as in the preceding case; their biomass reached 13 kg/m^2 at the depth of 2 m (on buoy No. 45).

The mean biomass of hydroids for the entire area equals 2770.5 g/m^2.

Barnacles can be considered to be secondary organisms for this area, because their number and their size were relatively small (0.3-0.5 cm); their development was considerable only on those spots of buoys where the population of hydroids was insignificant. As a whole, the barnacle biomass for the area was 745.75 g/m^2, while their greatest biomass was observed on the water line of buoy No. 46, there the value reached 1430.0 g/m^2. It is evident that in this type of marine fouling, the development of barnacles was obstructed. Occupying the first layer and being the first inhabitants on buoys, the barnacles later become subordinated forms of marine fouling. Meanwhile, the development of hydroids is profuse in this area. In places where the hydroids are bountiful, the number of barnacles is small and their sizes are limited, they die out, despite having been the first settlers on buoys. Of the other subordinated organisms we have a small number of crustaceans (Idothea baltica, observed on buoy No. 44) and a diverse and rather bountiful plant world. The main foulers are Cladophora rupestis, Enteromorpha crinita, Ectocarpus silculosus and E. siliculosus f. varians, as well as Porphyra atropurpurea.

The total biomass of marine fouling reached in this area is 3605.5 g/m^2.

The hydroids form a continuous cover on the underwater part of the buoys. However, their main mass forms a clearly pronounced thick belt (approximately 0.5 m wide) surrounding the buoy at the depth of 2 m.

Here we have two species of hydroids: Cordylophora caspia (small quantity) and Hydroidea sp. Accurate determination of the latter was hindered because of the absence of hydranths (the marine fouling on buoys was investigated in the winter). However, on the basis of the branching and structure of the stem, its length and color, as well as ecological properties, this species is very reminiscent of Perigonimus megas of the Kiel Canal, described by Kinne (1956b). Hydroidea sp., as Perigonimus megas. lives in diluted water (from 1 to 6°/o), is thermophilic, reduces hydranths and gonophores at temperatures below 9-12°, i.e. from October to May the species does not have them. Hydroidea sp. reproduce intensely in July and August, but growth ceases at a temperature of 14° (Kinne, 1956a). Formerly, Perigonimus megas was not discriminated from Cordylophora caspia and therefore its distribution is still little known. In 1960-61 it was found in the Sea of Azov (Simkina, in this compilation) and the Caspian Sea (Zevina et al., in this compilation). I consider, like D. V. Naumov does, that Hydroidea sp. is a perigonial form which could find favorable conditions for its growth in Frisches Haff.

In the summer of 1961 we examined buoy No. 44, which had been anchored in the water five months (from April through August) west of Baltiysk. The marine fouling on it differed considerably from the fouling of the same buoy in 1960, although hydroids (Cordylophora caspia) dominated, as in 1960. The hydroids were found at the depth of 1 to 5 m, forming a thick belt at the depth of 2 m from the water surface. Their biomass equaled 597.4 g/m^2. In contrast to 1960, the entire surface of the buoy (in the underwater part) was strewn, as with beads, with young mytilaceans whose length did not exceed 0.2 cm, the mean biomass being 13.3 g/m^2. The appearance of mytilaceans in the area, where they were not found in 1960, must be caused by a certain increase in salinity and rise in water temperature during the first half of 1961. The latter fact was, evidently, associated with the warm winter of 1960/61 when the quantity of ice was small in the sea. Its melting, combined with decreased floods in the rivers of the Baltic basin, did not create a sharp decrease of salinity in April-May 1961.

Barnacles occupied the first layer in the biocoenosis, and they were very small in size. Despite their great numbers (to 10,000 ind/m^2) their mass was insignificant (on the average 539.3 g/m^2). A small quantity of diatoms was observed along the water line. The general biomass of fouling on the buoy equaled 1151.2 g/m^2 in 1961.

CONCLUSIONS

According to the character of fouling on protective barriers, nine areas can be singled out in the southeastern part of the Baltic Sea (see figure). As demonstrated by observations, a gradual complication in the composition of marine fouling takes place along the coast of the Gulf of Finland, from Kronshtadt to the area of large Estonian Islands. This is expressed by an increase in the number of species and the quantity of biomass in marine fouling, in the appearance of stratification and intensification of competition for living space and food among the foulers. Thus, from a weakly pronounced fouling, scattered over the surface of buoys in separate spots in Areas I and II, a continual cover of foulers forming several layers was observed in Areas IV and V. However, if in Area IV the main mass fouling is made up of barnacles, in Area V the main mass consists of barnacles and mytilaceans. The character of marine fouling in coastal belts (VI and VII) is very similar to that of Area V, the only differences being in the quantity of fouling (2707.0 g/m^2 in Area V, 2030.0 g/m^2 in Area VI, and 1500.0 g/m^2 in Area VII).

The marine fouling in the Gulf of Riga and Frisches Haff (Areas VIII and IX) bears a peculiar character. Thus, in the Gulf of Riga a sharp impoverishment of qualitative composition in marine fouling is observed; only barnacles participate in the process; however, their biomass increases considerably (to 3023.7 g/m^2). In Frisches Haff hydroids are bountiful, predominating over all the foulers, including barnacles. The total biomass for the area (IX) is 3605.5 g/m^2, which is the highest of the regions of the Baltic Sea that was investigated. The enrichment of the composition of marine fouling from east to west in the Gulf of Finland, i.e. toward the exit to the sea, as well as the peculiar types of foulers in the Gulf of Riga and Frisches Haff, is closely associated with various ecological conditions, such as temperature, salinity, currents, the quantity of nutrients, as well as other conditions and their combinations, the analysis of which is difficult for the time being.

A new species of hydroids, which should evidently be named <u>Perigonimus megas</u> Kinne, was disclosed in Frisches Haff. /50

Generally, it must be conceded that the fouling in the Baltic Sea is insignificant. C. the whole, the biomass of foulers during 7-8 months, including the entire warm season, was 2400.0 g/m^2 for 1960.

As to the mutual relations among the components of fouling, the foulers of Frisches Haff deserve attention: here hydroids subordinate and oppress the first settlers — barnacles — causing at times their destruction. In this case, a well pronounced shift in forms — succession — manifests in just one warm season.

The biocoenosis of marine fouling investigated by us does not reach a stable (climax) phase of development, as is the continuous cover of mytilaceans. This is obstructed mainly by the limited time during which the buoys were anchored in the sea (less than a year). In addition, the rate of growth of mytilaceans is greatly retarded in the Baltic Sea (small forms, in addition to normal individuals, are typical of the sea where a normal decrease of salinity is observed. Zenkevich, 1947)

Because in certain instances the marine fouling can reach a considerable quantity in the Baltic Sea and can, in addition, further the corrosion of the metal surface of buoys, the buoys must be covered with antifouling paint prior to their anchoring in the sea in order to normalize and make their utilization convenient.

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MARINE FOULING IN THE WHITE SEA

Abstract

Over 20 species of animal macrofouling organisms have been found on the buoys in the White Sea, the leading forms being _Balanus crenatus_, _B. balanoides_, _Mytilus edulis_, _Obelia longissima_ and _Dendronotus frondosus_. According to the qualitative and quantitative differences in the character of fouling, the White Sea may be divided into five regions. The fouling of the "Funnel" and "Mouth" of the Sea is scarce and that of the Mezenskaya guba is a bit heavier. The heaviest fouling was recorded in the most remote parts of bays running deeply inland. An average quantity of fouling on buoys, which are usually exposed in the White Sea for a period of six to six and one-half months, amounts to 0.4-0.5 kg/m^2.

The marine fouling in our northern seas has been little studied. Only a study by L. A. Zenkevich (1935) can be mentioned. The author discusses marine fouling in Yekaterin(skaya gavan') Harbor (Kol'skiy zaliv). A detailed compilation (Marine Fouling and Its Prevention, 1957*) lists the results of investigations of marine fouling on buoys anchored between Newfoundland and the Gulf of Mexico and between Puget Sound and Southern California, i.e. in temperate latitudes; besides, this compilation does not list quantitative data at all.

There are no investigations dealing directly with marine fouling in the White Sea, but its benthos and plankton have already been sufficiently well investigated. In addition, numerous studies deal with the ecology of organisms found in marine fouling.

I studied the fouling on buoys anchored in various parts of the White Sea (fig. 1), as well as along Novaya Zemlya and in Pechorskaya guba. Most of the buoys were in the water from the end of May through November (5-6 months) [sic!]; the buoys of the Severodvinskiy reyd were in the water from 13 May through the end of November (6 1/2 months), buoys A, Б, B, and Г were in the water from the end of June through the end of November (5 months), the buoys of Pudozhemskogo ust'ya and Chizha

*Translation date, English to Russian. (Editor's note).

River were in the water from the beginning of June through the beginning of December (6 months), but the buoy of Novaya Zemlya and Pechorskaya guba were exposed from the end of June through the middle of November (4 1/2 months).

Samples were taken from various sections of buoys: along the water line, at the depth of 1 m from the vertical side of body, at the depth of 1-1.5 m from the lower side of body, at the depth of 3-5 m from the tube of the buoy and at the depth of 4-6 m within the tube at the opening. The living conditions and species composition of organisms differed considerably with various places on buoys. There was sufficient illumination along the water line and also often intense wave motion. Algae prevailed here. At the depth of 1 m the illumination was not so good and wave motion was less intense. Animals prevailed here, though also often algae were found. In the lower part of the buoys, the illumination was considerably weaker, and the vertical surface was replaced by horizontal surface. Only animals were found here. At the depth of 3-5 m, the illumination on the vertical surface was weak, and the wave motion was not intense. Also only animals were observed here. Light and wave motion were completely absent in the tube. Nevertheless, water exchange took place because the buoy oscillating with waves was displaced as regards the layers of water, and the fouling in the tube near the opening was usually very considerable, often denser than on the external surface of the tube. Farther from the opening, the fouling gradually decreased in the tube, and at the distance of 2-4 m disappeared altogether. Only large individual mytilaceans were found here, which had undoubtedly moved in, but had not developed in the section. Evidently, the water exchange in the deep portion of the tube was weak and did not offer chances for the development of foulers. As a rule, the samples were taken from similar places; however, sometimes it was not possible (if the marine fouling had been removed by ice or during the lifting of buoys aboard the vessel).

The reasons for taking samples from buoys were as follows. The conditions on buoys are similar to conditions in the upper sublittoral because the buoys are not subjected to drying, as is also the case with the hulls of vessels. Thus, the organisms that occupy buoys in the same areas could occupy the hulls of vessels as well, and the distribution of foulers on buoys could help clarify the potential foulers on vessels. /53

The quantitative study of the population of the solid bottom of the sublittoral is prevented by the absence of the needed tools. Only a

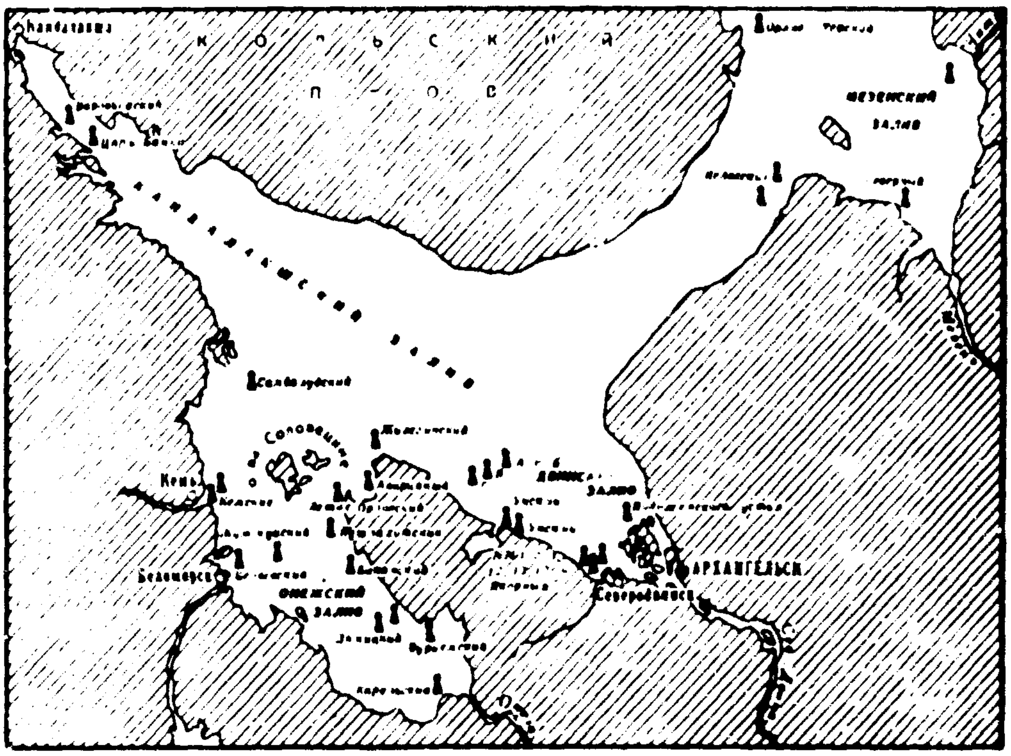


Fig. 1. Location of buoys from which samples of marine fouling were obtained and the names of the buoys.

The geographical names and those of the buoys are listed here clockwise from the upper left-hand corner. Kandalakshskiy zaliv area: Kandalaksha - Vorob'yevskiy - Tsar'-banka; Kol'skiy poluostrov; Mezenskiy zaliv area: Orlovsko-Terskiy - Chizha - Mezenskaya guba (Mezenskiy zaliv) - Severnyy - Kedovskiy - Mezen' (River); Dvinskiy zaliv area: Pudozhemskogo ust'ya - Arkhangel'sk - Severnaya Dvina (River) - Severodvinsk - No. 1, 2, 3, 1?, 13, 17 and Yakornyy - Unskiy 1 - Unskiy 2; Onezhskiy zaliv area: Zhizhginskiy - , B, A, and - Avariynyy - Letne-Orlovskiy - Pushlakhotskiy - Bakanskiy - Lyamitskiy - Pur'yemskiy - Onega (River) - Karel'skiy - Onezhskaya guba (Onezhskiy zaliv) - Belyayevskiy - Belomorsk - Zhemuyskiy - Kemskiye - Kem' - ostrova Solovetskiye - Sambaludskiy.

diver is in a position to take quantitative samples from solid bottom. Therefore, despite the fact that there are quite a few studies dealing with quantitative investigations of the benthos in the White Sea, the data on the solid bottom of the sublittoral are far from complete in these studies. The time during which the buoys had been in the water has always been accurately known.

Milne (1940) notes that the organisms living on the bottom usually penetrate fresh water basins farther than the organisms living on buoys, which he considers a typical characteristic of life on buoys.

The number of species found among the foulers on buoys exposed in the White Sea (about 20 species[1]) is insignificant in comparison with the total number of animal species constituting the bottom fauna of the sea (about 800). On the basis of frequency of occurrence, hydroids constituted the first place (95.2°/o), mytilaceans the second (64.4°/o), which were followed by Balanus crenatus (62.8°/o), nudibranchiate mollusks (47.6°/o), B. balanoides (42.0°/o), bryozoans (33.6°/o), Asterias rubens (19.6°/o), gammarids (16.8°/o), caprellids (14.0°/o), Anomia squamosa (8.4°/o), Verruca strömia (5.6°/o), B. balanus (2.8°/o).

K. M. Deryugin (1928) distinguishes seven main areas in the White Sea: /54
1) Estuary of Severnaya Dvina, 2) Dvinskiy zaliv, 3) Central Basin, 4) western part of Kandalakshskiy zaliv, 5) Onezhskiy zaliv, 6) Gorlo, and 7) Voronka. The distribution of marine fouling on buoys anchored in the White Sea is patterned after a scheme by Gur'yanova (1948), but the middle part of the sea and the open portions of Kandalakshskiy zaliv, Onezhskiy zaliv, and Dvinskiy zaliv are singled out as a special area of open sea. We did not have data on the deep section of the sea.

Thus, on the basis of qualitative and quantitative differences in marine fouling, the following areas of the White Sea were singled out: 1) Voronka, 2) Gorlo, 3) Mezenskiy zaliv, 4) coastal belts of Dvinskiy zaliv, Onezhskiy zaliv, and Kandalakshskiy zaliv, 5) open parts of the sea and the last three gulfs.

1. Voronka area. Only one buoy was examined - namely, Orlovsko-Terskiy (see fig. 1). It differed considerably from the buoys of other portions of the sea by almost complete absence of fouling. The overall biomass of marine fouling constituted only about 1 g/m² and it consisted of individuals of Balanus balanoides attached in cracks and other hidden places of the buoy. It seemed that a strong current in the area, which was evidently carrying sand and shingle, had torn off the foulers from the buoy.

[1]The identifications were gladly made by the following experts: A. D. Zinova - algae; S. D. Stepan'yants - hydroids; E. F. Gur'yanova - amphipods; S. V. Vasilenko - caprellids; I. S. Roginskaya - nudibranchiate mollusks; M. G. Gostilovskaya - bryozoans; V. V. Khlebovich - polychaets.

2. Gorlo area. Two buoys on banka Kedovskaya Koshka were examined. This area, like the Voronka area, is characterized by strong tidal currents. The marine fouling on buoys was very weakly developed (on the average 10-20 g/m^2), despite a belt of green algae with a biomass of about 600 g/m^2, which was observed along the water line. Animals formed isolated spots in places protected from the action of water. A few hydroids, Balanus balanoides and B. crenatus, as well as individual gammarellus homari were found in the area.

3. Mezenskaya guba (Mezenskiy zaliv) area is characterized by great speeds of tidal currents which intermix the entire water layer. In this gulf, we succeeded in obtaining only qualitative samples from buoys Severnyy, Nes' and three buoys anchored in the estuary of Chizha, because the fouling was dry at the moment the samples were collected. It can, however, be said that the biomass of fouling made up about 200-300 g/m^2 in this area. The arrangement of fouling was as follows: a belt of algae with hydroids along the water line; hydroids together with mytilids, small colonies of bryozoans and barnacles at the depth of 0.5 m. Hydrological conditions varied from place to place, which created differences in the fouling. Thus, on buoy Severnyy we observed hydroids (Tubularia sp., Obelia sp.), as well as small mytilids not exceeding 7 mm and individual Balanus balanoides not exceeding 13 mm. The fouling of buoys in the estuary of Chizha consisted of hydroids (Obelia sp.) and crustaceans B. balanoides and B. crenatus 9-10 mm long. The absence of mytilids on the buoy could be the result of a rapid current and a low salinity. The most abundant and varied fouling was found on a buoy near Nes'. Here, in addition to algae, we found hydroids (Obelia longissima), newly settled mytilids not exceeding 11 mm in length, small settlements of bryozoans and caprellids - all occupying a belt along the water line.

The number of species composing the fouling on buoys anchored in Mezenskaya guba was very insignificant, which corresponds to data on the fauna of this area listed by Gur'yanova (1957), who considers that the qualitative poverty is associated with quantitative poverty.

4. The area of coastal belts of gulfs Dvinskiy z., Oneshskaya guba (Oneshskiy z.), and Kandalakshskiy z. Dvinskiy zaliv is characterized by weak currents and sharp temperature and salinity stratifications: the warm diluted waters of Severnaya Dvina, which progress over the surface of the gulf, are replaced by cold saline water at the depth of 10-12 m. The salinity also varies from the estuary of Dvina toward the exit of the gulf. Therefore, the fouling on buoys anchored in the estuary area differs from the fouling on buoys in the entrance of Unskaya guba. /55

In the estuary of Severnaya Dvina the following buoys were anchored: Yakornyy, all the buoys of Severodvinsk region, including nos. 1, 2, 3, 12, 13, 17, and the buoys Pudozhemskogo ust'ya. These buoys were characterized by the greatest biomass of fouling in the White Sea - the average being 2 kg/m^2, the maximum 5 kg/m^2. The following animal foulers were observed on the buoys: mytilids, not exceeding 18 mm, hydroids Obelia longissima; but on buoy Unskiy 1 we found Tubularia sp., Balanus crenatus (the carino-rostral diameter ranging from 4 to 18 mm), bryozoans, which at times made up a considerable portion of fouling, individual polychaetes, nudibranchiate mollusks, and stars. Mytilids were in predominance (fig. 2 and 3).

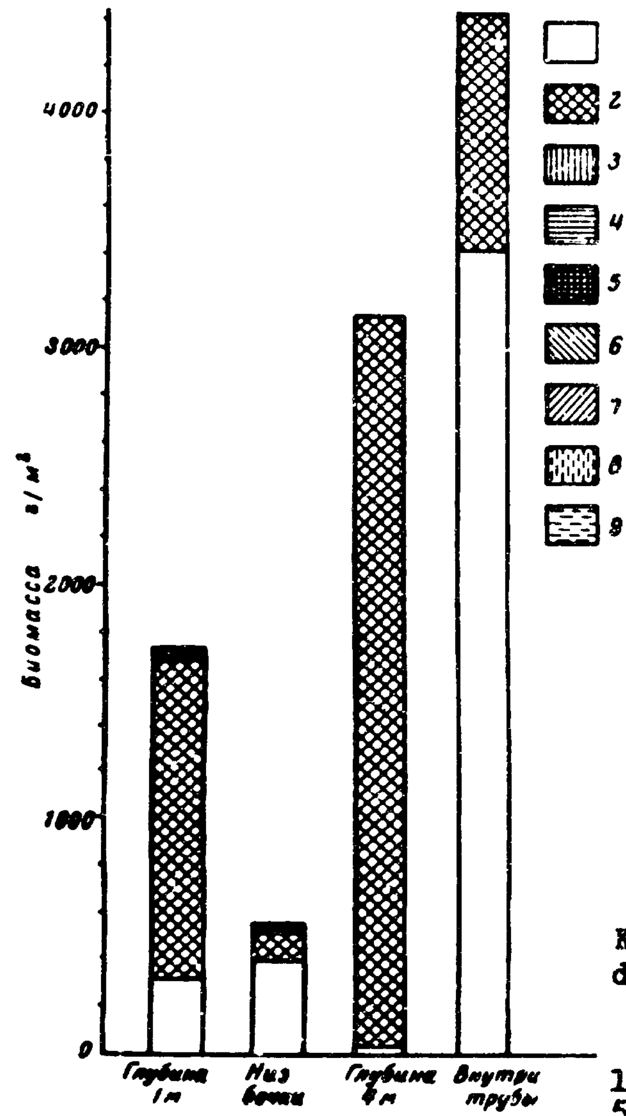
The fouling on buoys anchored in the entrance to Unskaya guba was characterized by minute mytilids (to 7 mm long), hydroids (Tubularia sp.), and a multitude of caprellids, especially on buoy Unskiy 2 (table 1).

Table 1

Marine Fouling on Buoys Anchored in the Coastal Sectors of Dvinsk_ Zaliv

Buoy	Balanus crenatus	Hydroids	Bryozoans	Caprellids	Mytilids	Polychaetes	Nudibranchiates	Stars	Mean biomass, g/m^2
Severodvinsk									
No. 1	+	+	-	-	+	-	+	+	917
No. 2	+	+	-	-	+	-	+	+	808
No. 3	+	+	+	-	+	-	-	-	1860
No. 12	+	+	-	-	+	-	-	-	4950
No. 17	+	+	-	-	+	-	-	-	2680
Yakornyy	+	+	+	-	+	+	-	-	2470
Pudozhemskoye ust'ye	+	+	-	-	+	-	-	-	-
Unskiy 1	+	+	-	+	+	-	-	-	-
Unskiy 2	-	+	-	+	+	-	-	-	-

The mean biomass of foulers on the buoys equalled about 2 kg/m^2.



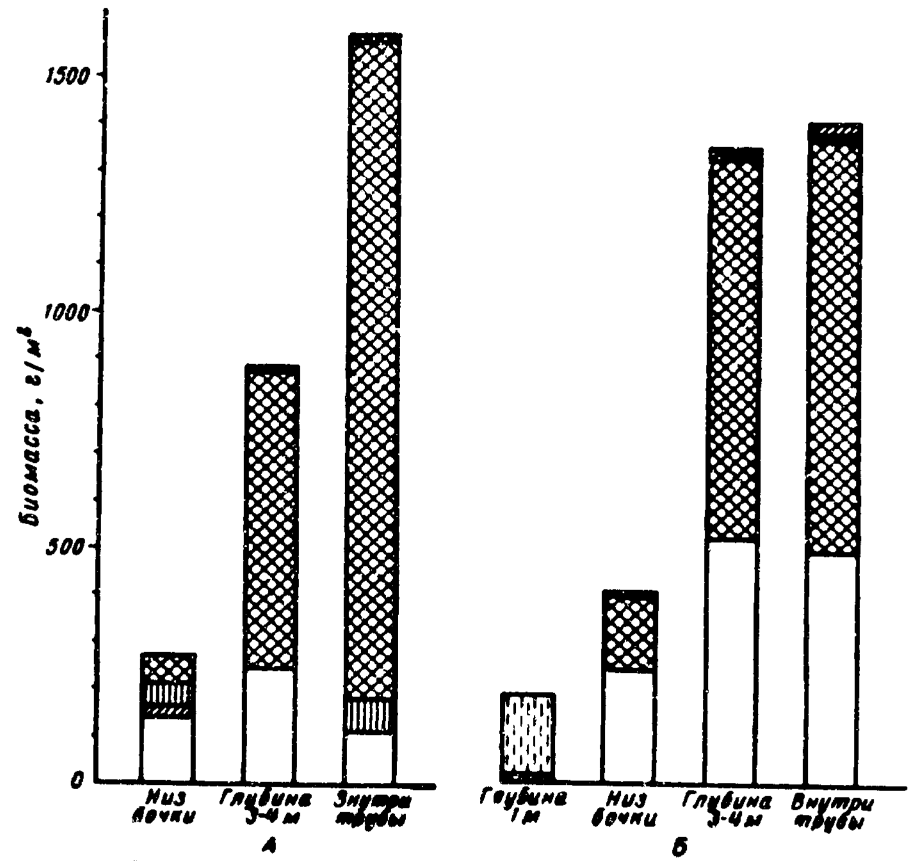


Fig. 3. The biomass of marine fouling.

A – on buoy No. 1; Б – on buoy No. 2.

Key. x axis: biomass in g/m². y axis: underpart of buoy-depth 3-4 m-inside of tube-depth 1 m-underpart of buoy-depth 3-4 m-inside of tube.

Fig. 2. The biomass of marine fouling on buoy Yakornyy. 1-hydroids; 2-mytilids; 3-Balanus crenatus; 4-B. balanoides; 5-caprellids; 6-nudibranchiates; 7-bryozoans; 8-algae; 9-others. The same designations are on the subsequent figures. Key. x axis: biomass in g/m². y axis: depth 1 m-underpart of buoy-depth 4 m-inside of tube.

The protected coastal sectors of Onezhskaya guba (Onezhskiy zaliv) are characterized by the type of fouling found on Pur'yemskiy and Karel'skiy buoys (table 2).

The great mass of fouling is associated with the accumulation of mytilids (fig. 4 and 5), reminiscent of mounds of coarse sand, which conceal the stolons of hydroids serving as substratum for the mollusks. The number of mytilids reaches 7,800,000 ind/m^2. Their accumulations include stars Asterias rubens, as well as caprellids. The number of hydroids Obelia longissima is very small, the mean biomass being 1.8 kg/m^2.

Table 2

Marine Fouling on Buoys Anchored in the Coastal Sector of Onezhskaya guba

Buoy	Balanus crenatus	Hydroids	Caprellids	Bryozoans	Mytilids	Stars	Mean biomass, g/m^2
Pur'yemskiy. . .	+	+	+	+	+	+	1584
Karel'skiy . . .	-	+	+	-	-	+	2027

An idea on the fouling of Kandalakshskiy zaliv is obtained from samples taken from buoys Vorob'yevskiy and Tsar'-banka (table 3). They were anchored in partly protected places, and the fouling on them is somewhat reminiscent of that in open areas consisting of a multitude of hydroids (Obelia longissima); however, mytilids prevail here (fig. 6 and 7) and the biomass of fouling is considerable, many times greater than in open areas.

The fouling on buoys is rather varied, the mean biomass being 1.2 kg/m^2.

5. Area of open parts of the sea and of the gulfs Dvinskaya guba, Onezhskaya guba, and Kandalakshskiy zaliv. This area is characterized by strong tidal currents and relatively saline water.

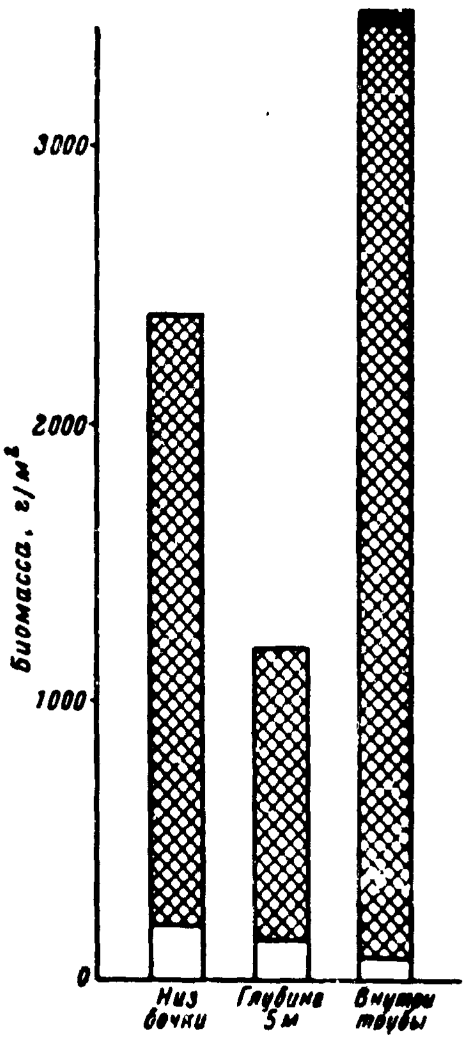


Fig. 4. The biomass of marine fouling on buoy Karel'skiy.

Key.
x axis: biomass in g/m^2.
y axis: underpart of buoy - depth 5 m - inside of buoy.

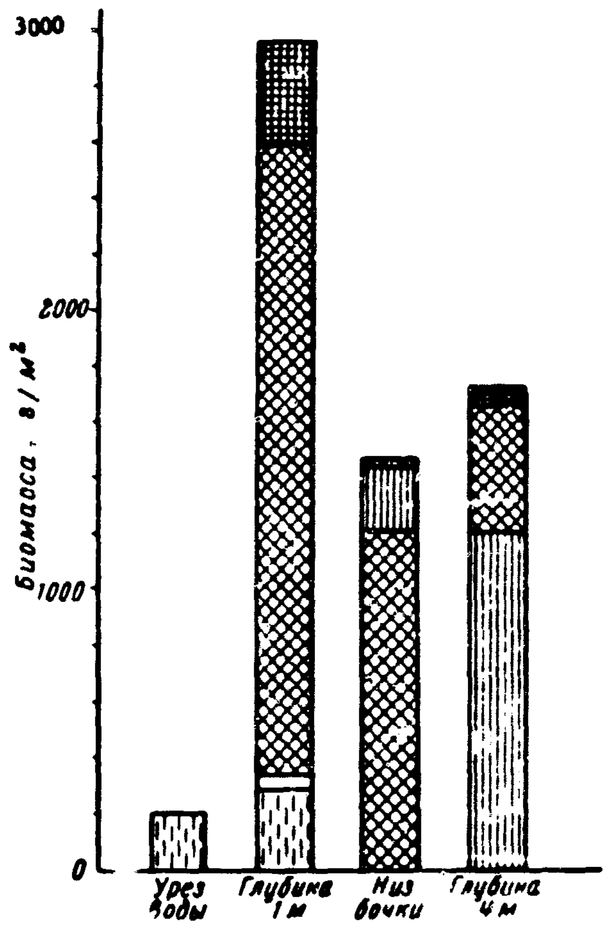


Fig. 5. The biomass of marine fouling on buoy Pur'yemskiy.

Key.
x axis: biomass in g/m^2.
y axis: waterline - depth 1 m - underpart of buoy - depth 4 m.

Table 3

The Fouling on Buoys Anchored in Coastal Sectors of Kandalakshskiy zaliv

Buoy	Balanus crenatus	B. balanoides	B. balanus	Hydroids	Bryozoans	Mytilids	Nudibranchiates	Other mollusks	Stars	Mean biomass, g/m2
Vorob'yevskiy. . .	+	+	-	+	+	+	+	+	+	1681
Tsar'-banka. . . .	+	-	+	+	+	+	-	+	+	784

The fouling consists mainly of hydroids (Obelia longissima) and the nudibranchiate mollusks associated with the former; the number of mytilids is small (fig. 8, 9, and 10). A small number of Sertularia cupressina L. was found on buoy Pushlakhotskiy, and Tubularia were observed on buoy Lyamitskiy. The biomass of fouling was small (table 4). The absence of crustaceans characterizes the fouling on buoys anchored in more exposed places (A, Б, B, Avariynyy, Sambaludskiy). Verruca was found only on the buoys that had been anchored along the west coast of Onezhskaya guba despite the fact that large quantities of this species is found to the east of the area, where it is one of the leading forms (Ivanova, 1957).

Typical, was the absence of caprellids. The variety of forms of foulers found on buoys anchored in more exposed locations was rather limited; if, however, a buoy had been anchored nearer to the coast, motile forms were found on it, such as gammarids and polychaetes. The mean biomass in this area equalled about 0.4 kg/m^2.

The buoys that had been anchored in waters southwest of Novaya Zemlya were covered with Obelia longissima and Balanus crenatus, the latter forming at places crowded settlements, so that the individuals had elongated lily-shaped forms, the base length being 3-5 mm and the height of specimens reaching 30 mm.

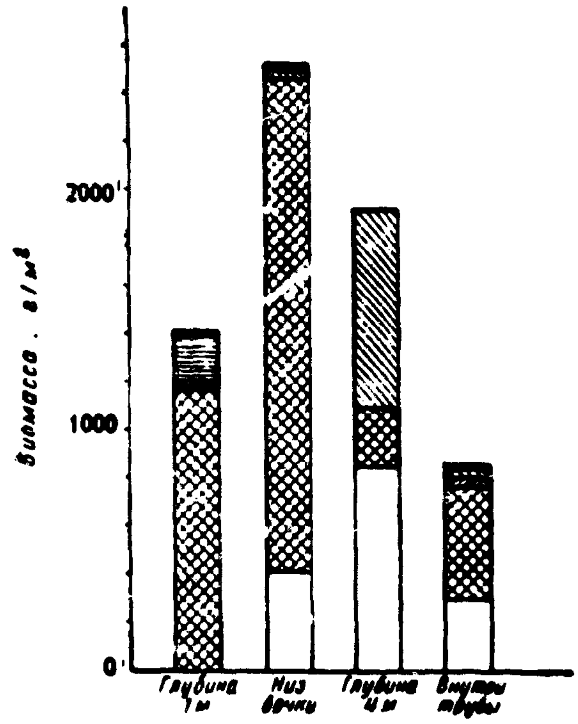


Fig. 6. The biomass of marine fouling on buoy Vorob'yevskaya.

Key.

x axis: biomass, g/m^2.
y axis: depth 1 m - underpart of buoy - depth 4 m - inside of buoy.

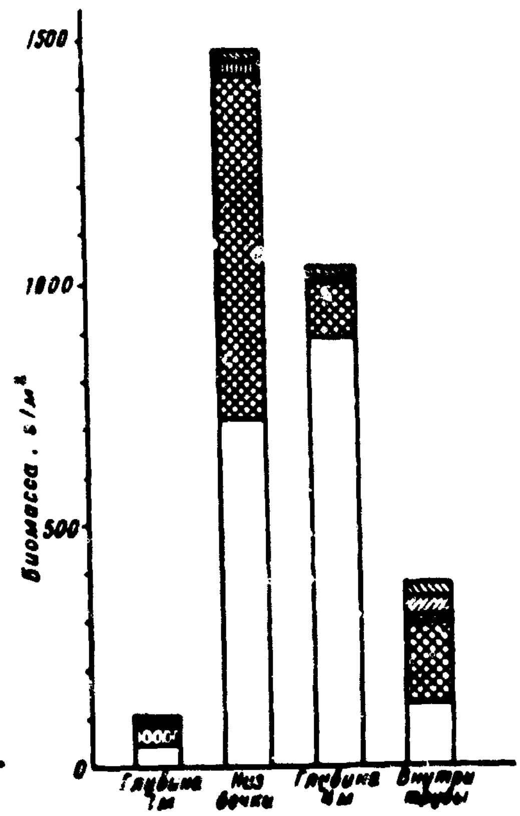


Fig. 7. The biomass of marine fouling on buoy Tsar'-banki.

Key.

x axis: biomass, g/m^2.
y axis: depth 1 m - underpart of buoy - depth 4 m - inside of buoy.

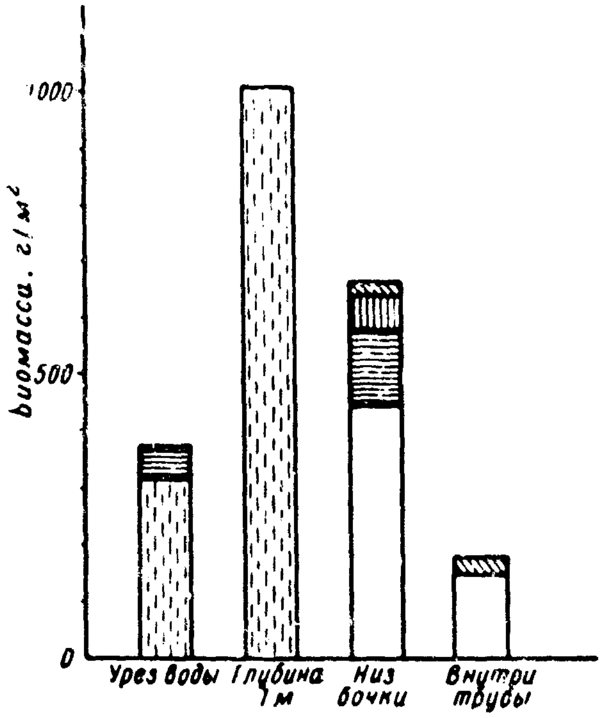


Fig. 8. The biomass of marine fouling on buoy o. Zhizhginskogo.
Key. x axis: biomass in g/m². y axis: waterline-depth 1 m-underpart of buoy-inside of buoy.

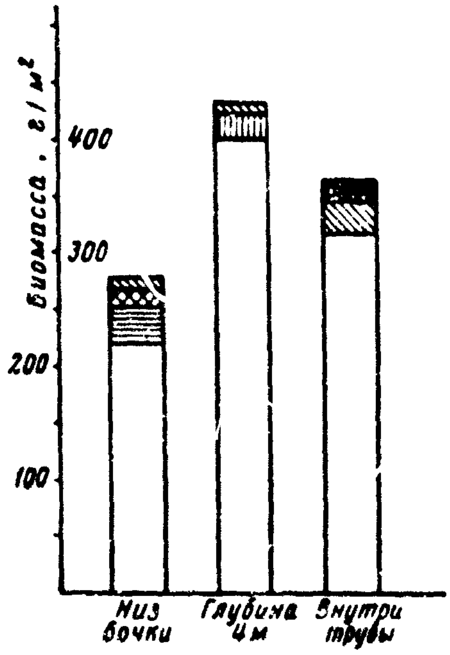


Fig. 9. The biomass of marine fouling on buoy Yuzhnyy-Kemskiy.
Key. x axis: biomass in g/m². y axis: underpart of buoy-depth 4 m-inside of buoy.

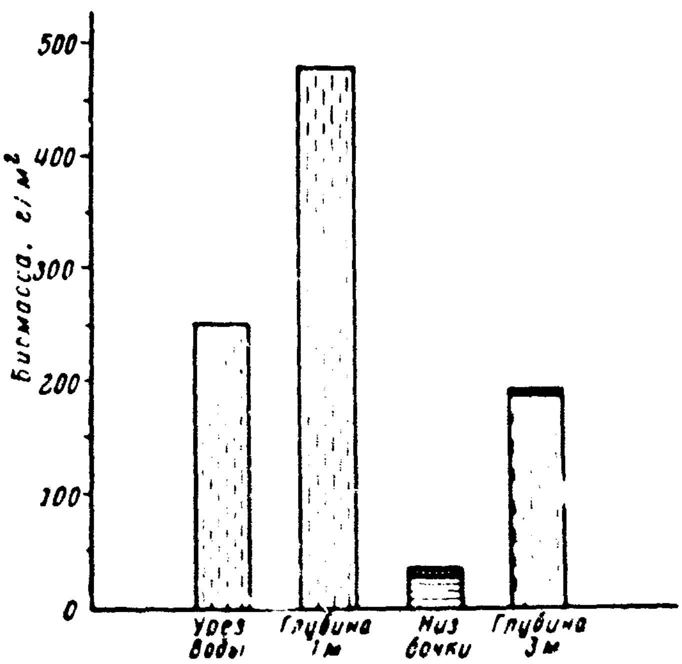


Fig. 10. The biomass of marine fouling on buoy Letne-Orlovskiy.
Key. x axis: biomass in g/m². y axis: waterline-depth 1 m-underpart of buoy-depth 3 m.

Table 4

Marine Fouling on Buoys Anchored in Exposed Parts of the Sea and of Dvinskaya guba, Onezhskaya guba, and Kandalakshskiy zaliv

Buoy	B. crenatus	B. balanoides	Verruca	Hydroids	Nudibranchiates	Bryozoans	Mytilids	Other mollusks	Polychaetes	Stars	Anomia	Gammarids	Mean biomass, g/m^2
A	–	–	–	+	+	+	+	–	–	–	–	–	569
Б	–	–	–	+	+	–	+	–	–	–	–	–	344
B	–	–	–	+	+	–	–	–	–	–	–	–	838
Г	–	+	–	+	+	–	–	–	–	–	–	–	321
Zhizhginskiy. . . .	+	+	–	+	+	–	–	–	–	–	–	–	569
Avariynyy	–	–	–	+	+	–	+	–	–	–	–	+	832
Letne-Orlovskiy . .	+		–	+	+	–	+	–	–	–	–	+	241
Pushlakhovskiy. . .	+	+	–	+	+	+	+	+	–	–	–	–	194
Bakanskiy	+	+	–	+	+	–	–	–	–	–	–	–	180
Lyamitskiy.	+	+	–	+	+	–	–	+	+	–	–	+	10
Belyayevskiy. . . .	+	+	+	+	+	+	+	–	+	+	+	–	570
Zhuzhmiyskiy. . . .	+	+	+	+	–	–	–	+	–	–	–	+	237
Vostochnyy Kemskiy.	–	+	–	+	–	–	–	–	+	–	+	–	246
Yuzhnyy Kemskiy . .	+	+	–	+	+	+	+	–	–	–	+	+	356
Sambaludskiy. . . .	–	–	–	+	+	+	+	–	+	+	+	–	833

The fouling of buoys taken from Pechorskaya guba consisted only of hydroids and B. crenatus. The number of hydroids was small, but that of B. crenatus reached 28,300 ind/m^2, the biomass being 1.5 kg/m^2. The base length of barnacles was 2 to 12 mm, the height reaching 13 mm.

If the buoys of the entire White Sea are examined, it can be said that the number of species participating in marine fouling is small and changing with areas. The leading forms are mytilaceans (Mytilus edulis), hydroids, crustaceans (Balanus balanoides and B. crenatus), and nudibranchiate mollusks. They are found throughout the White Sea. However, various species dominate in various areas and the mean biomass of marine fouling also varies with areas. In areas that are affected by strong currents, as for instance in Gorlo and Voronka, the fouling is insignificant. In exposed areas of the sea, also the currents affect fouling; however, the degree of influence depends on the type of organism: for mytilids, which cannot stick firmly to objects, a rapid current is obviously unfavorable.

On the basis of data listed by American authors (Marine Fouling and Its Prevention, 1957*), the rate of accretion in mytilids is correlated with the force of tidal currents because a rapid motion of water improves the feeding conditions of mytilids. This is, however, applicable to a degree. The current speed given by the authors ranges between 0.41 and 1.02 knots, whereas the current speed in the White Sea, according to data by Deryugin (1928), is 3.5–4 knots in the Voronka and Gorlo; but at such speeds the mytilids are unable to stick to a chosen object, neither can barnacles settle on the objects.

According to Smith (1946), Balanus improvisus is capable of sticking to objects at current speeds not exceeding 0.5 knots, Dasychone conspersa can do it at speeds to 1 knot. Crisp (1955) thinks that the settlement of barnacles is impossible at gradient speeds exceeding 500 sec^{-1} (sic!), which corresponds to a current speed of 1-2 knots; however, in protected places formed by rough spots of the hull of a ship, the gradient speeds of currents are smaller and the larvae are capable of settling at speeds to 5 knots. But in places where the water movement is almost absent, the barnacles do not live; this is especially true of B. balanoides.

The conditions in exposed areas of the sea are unfavorable for the formation of fouling, and the quantity of larvae in water is smaller than in coastal belts.

The turbidity of water exercises a great effect on algal fouling, because algae do not grow in the absence of light. It is seen from fig. 9 that the algae prevail even at the depth of 3 m on buoy Letne-Orlovskiy, which was anchored in transparent water. Similarly, the algal biomass on a buoy at o. Zhizhgin (Zhizhginskiy) was more than 1 kg/m^2 at the depth of 1 m. Nowhere in protected places and turbid water have been observed such great masses of algae at the depth of 1 m, and their existence at the depth of 3-4 m. The mean biomass of marine fouling on buoys that had been in the water for six to six and one-half months is about 400—500 g/m^2 for the entire White Sea.

*Translation date, English to Russian. (Editor's note)

According to L. A. Zenkevich (1935), the annual fouling in Yekaterinskaya gavan' does not exceed 1.5 - 2 kg/m^2. A similar quantity of fouling can accumulate in a year in bays and harbors of the White Sea, as well as in the Baltic Sea (Arbuzova, in this issue). These numbers are completely incomparable to the biomass of fouling in our southern seas. Thus, the mean biomass on buoys anchored for 7-8 months in the northern Caspian sector was 11.5 kg/m^2 (Zevina and Starostin, 1961), i.e. 23 — 25 times more than in the White Sea. According to M. A. Dolgopol'skaya (1954), the biomass of marine fouling on test panels submerged in the Black Sea reached 548 g/m^2 in a month, i.e. 106 kg/m^2 a year.

THE MAIN FORMS FOUND IN MARINE FOULING IN THE WHITE SEA

Hydroids were found on all buoys, except for Tersko-Orlovskiy, anchored in Voronka. Altogether, four species of hydroids were identified of the 81 species of hydroids listed by D. V. Naumov (1960) for the White Sea; namely, Obelia longissima (Pallas), Obelia sp., Tubularia sp. and Sertularia cupressina L.

Obelia longissima was dominant, being found in all the areas of the White Sea, as well as on buoys at Novaya Zemlya, in Pechorskaya guba, and the Barents Sea. Sertularia cupressina was found once on buoy Pushlakhotskiy. Tubularia sp. was found on buoys Lyamitskiy, Severnyy, and Unskiy. Obelia sp. was observed on buoys anchored in Mezenskaya guba. Because the material was not well preserved it was impossible to identify the latter as to species.

Hydroids were found beneath the belt of algae of buoys. Usually a large quantity of hydroids was found on the underpart of the buoy and on the outside of the tube. In the tube, the number of hydroids was, as a rule, smaller, which is of course associated with a scant supply of oxygen. The mass of hydroids is greater on buoys that are anchored in exposed parts of the sea (table 5). The biomass of hydroids is, on /62
the contrary, greater on buoys anchored in coastal belts; this is explained by the fact that the greater quantity of barnacles and mollusks creates a greater area for the settlement of hydroids and other foulers, as it was observed in the Caspian Sea (Zevina and Starostin, 1961).

In marine fouling on buoys the biomass of hydroids was sometimes significant - as much as 3420 g/m^2, the mean value being of the order of 200-400 g/m^2.

Table 5

Biomass of Obelia longissima in Marine Fouling on Buoys in the White Sea

Buoy	Mean biomass, g/m^2 of hydroids	Mean biomass of fouling	Hydroids, °/o of the total biomass
Protected area	473	1491	31.8
Exposed area	313	440	71.1

Balanus balanoides is one of the most thoroughly investigated species in the White Sea, as well as in other seas in the Soviet Union and abroad. According to V. V. Kuznetsov (1960), the nauplii of B. balanoides appear by the end of May and the beginning of June, and young barnacles appear by the end of June and the beginning of July. Sometimes the metamorphosis is delayed and the young appear only in September or not at all.

In my collections obtained from buoys, B. balanoides made up 42.0°/o to a depth of 1—1.5 m. Its quantity was very small - not more than 300 ind/m^2, the biomass being 210 g/m^2. V. V. Kuznetsov and T. A. Matveyeva (1949) mention 48,000 ind/m^2 of the species for the littoral of the East Murmanskiy bereg, but M. N. Sokolova (1951) mentions the highest number - 80,000 ind/m^2 - for the littoral of Kandalakshskiy zaliv of the White Sea.

In the Sea of Okhotsk, B. balanoides forms large accumulations in the sublittoral belt, reaching 1700 ind/m^2 and a biomass of 3300 g/m^2 (Savilov, 1957a). The small quantity of B. balanoides found on buoys in 1959 seems to be typical only of this year; in other years it can be considerably greater.

B. balanoides was found in the fastest current on a buoy at mys Orlov (Orlovsko-Terskiy), where nothing else was seen in addition to this species, not even hydroids.

This species is not found in the estuaries of gulfs, where the salinity of water is low. Thus, it was not observed on a buoy at Severodvinsk and on other buoys anchored in the estuary of Severnaya Dvina; neither was it found on buoys Pur'yemskiy and Karel'skiy, of course, because of the dilution caused by the Onega River. According to data by V. I. Zatsepina, L. A. Zenkevich, and Z. A. Filatova (1948), B. balanoides does not live in Kol'skiy zaliv where the salinity is less than 20°/oo, but in the Kiel area the species is found at salinities 8-13°/oo (Buchholtz and Schultz, 1954). Tests by Barnes (1953) demonstrated that with a decrease of salinity to 18°/oo the nauplii feel quite well, but further survival depends on the length of time they have to live in a water with low salinity. G. M. Belyayev (1949) reports that B. balanoides of Kandalakshskiy zaliv lead active lives at salinity ranges from 12-15 to 45°/oo.

As to the growth of B. balanoides, their size exceeded many times that of barnacles living in the littoral belt. On buoys Belyayevskiy and Zhuzhmuyskiy, which had been anchored along the Karelian coast of Onezhskaya guba, we found extremely large individuals: the length of their carino-rostral axis was 20 mm. The largest species were found in the same place where Verruca was observed. Evidently, the conditions for both of the species were most favorable in the area. Large B. balanoides reaching the length of 18 mm were found on buoy Vorob'yevskiy in Kandalakshskiy zaliv. In Gorlo and Voronka, where the current velocity was very great, B. balanoides was considerably smaller, reaching the length of 12 mm; also in Mezenskaya guba, their length was limited to 10-13 mm in places where they were observed.

According to data by A. I. Savilov (1957b), the growth rate of B. balanoides on the littoral of Kandalakshskiy zaliv was small. Even at the most favorable conditions the length of one year old barnacles was 11.5 mm, and the length of 20.5 mm was reached only at the age of five years. The same author notes that the sublittoral belt is characterized by the absence of appreciable accumulations of barnacles, but in places where they are found, their growth rate is high and sizes especially large. Both of the assumptions are confirmed by data obtained by me. The sublittoral conditions are favorable for barnacles, because they can feed all the time, and the water movement in shallow water is sufficient for satisfying their food and oxygen requirements. Pyefinch (1950) maintains that the growth rate of B. balanoides is accelerated on the hulls of ships in the sublittoral belt c?(sic!)a. According to Barnes and Powell (1953), the barnacles when being completely submerged reached the length of 1?.5 mm by the end of the first year, but according to Crisp (1960), the length was 17 mm in the same conditions.

All the B. balanoides collected by me had a conical form. The reason was that the population density, as was mentioned above, was not great. M. N. Rusanova (1959) objects to measuring only the diameters of the shells when investigating the growth of barnacles, because the volume of the shells with the same length of diameter may be different. This is true if barnacles that have grown in various conditions of accumulations are compared. Therefore, in order to make my data comparable to the data of other authors, I present data on the volume of the shells in addition to linear measurements (table 6).

Table 6

The Size of the Largest Balanus balanoides Obtained from Various Buoys

Buoy	Place on buoy	Size of barnacles (length x width x height), mm	Volume of shells, mm^3
Vorob'yevskiy.	Depth 1 m	19 x 18 x 7	2394
Zhizhginskiy	Underpart	16 x 14 x 9	2016
Yu. Kemskiy.	Underpart	13.5 x 12 x 6	972
Zhizhginskiy	Water line	15 x 15 x 4	900
Bakanskiy.	Depth 1 m	12.5 x 11 x 5	685
Pur'yemskiy.	Underpart	13 x 13 x 4	676
Tersko-Orlovskiy . . .	Underpart	12.5 x 10.5 x 5	656
Letne-Orlovskiy. . . .	Underpart	12 x 9 x 6	648

A. I. Savilov (1957b) maintains that in favorable conditions B. balanoides becomes sexually mature in the first year of life. I found well developed gonads in species taken from buoys in November - December.

Balanus crenatus. The frequency of occurrence of this species equals 63.2%. The species is seldom found in exposed portions of the sea and in areas with warm currents, while in gulfs it is found on all buoys. Thus, at the estuary of Severnaya Dvina in Dvinskaya guba, B. crenatus was found on all buoys, whereas on buoys A, Б, and B, anchored in the entrance to the gulf, almost in the open sea, the species was not observed. B. crenatus was not observed on buoys Avariynyy and Sambaludskiy, which were anchored at the entrance to Onezhskaya guba, but on the other buoys anchored in the gulf it was found everywhere.

In comparison with B. balanoides, B. crenatus does not tolerate a rapid current; but it is less sensitive to decreased salinity. The tests carried out by Barnes (1953) show that the larvae of B. crenatus tolerated low salinities to 15°/oo. E. M. Kreps (1925) established that the critical minimum salinity for the species is 4°/oo, below which a normal existence is not possible. This species is considerably more cryophilic than B. balanoides.

In marine fouling on buoys anchored in Novaya Zemlya and Pechorskaya guba areas, only B. crenatus was found.

The size of the barnacles found on buoys appeared to be very considerable. In cases when, because of the absence of accumulation, the barnacles had a conical form, the carino-rostral diameter of B. crenatus reached the length of 25 mm at its base. The largest barnacles were observed in protected places of Onezhskaya guba, on buoy Pur'yemskiy, in Kandalakshskiy zaliv, on buoy Tsar'-banka, at o. Zhizhgin, and at Severodvinsk in the protected section of Dvinskaya guba. In the Novaya Zemlya area the settlements of B. crenatus were crowded; the length reached at a small diameter of 3-5mm was 30 mm; the same was observed in the entrance to Pechorskaya guba, but the degree of accumulation here was smaller; therefore the base diameter of barnacles ranged from 2 to 11 mm and height from 10 to 11 mm; in this, as well as in other cases, the buoys had been staying in the water only four and one-half months.

Such a rapid growth was not unusual for B. crenatus. According to data by Pyefinch (1948), along the coast of Great Britain B. crenatus reaches the length of 20-22 mm in three to four months, and the April settlers may produce larvae in July.

B. crenatus found on the hulls of cutters navigating in the Vladivostok area from May through December reached the diameter of 24-28 mm (Tarasov and Zevina, 1957). According to Caspers (1952), the barnacles of this species found on buoys in the estuary of the Elbe reached the length of 22 mm in a year.

On the greater part of the buoys anchored in the White Sea, B. crenatus was found in small quantities; only on buoy Pur'yemskiy did the number of the species reach 1300 ind/m^2, the biomass being 1160 g/m^2, but on buoy No. 12 at Severodvinsk, the magnitudes were 7600 ind/m^2 and 2950 g/m^2, respectively. In Pechorskaya guba the quantity of B. crenatus was greater, reaching 28,300 ind/m^2, the biomass being 1500 g/m^2. A somewhat greater amount of barnacles was found on buoys in Novaya Zemlya area.

On the buoys of the White Sea the biomass of B. crenatus is considerably smaller than the biomass of the species at Seattle, where the quantity of biomass reached 20 kg/m^2 in 10 months.

B. balanus was found only once (2 ind., 10-12 mm long) on buoy Tsar'-banka in Kandalakshskiy zaliv. According to H. Barnes and M. Barnes (1954), B. balanus in the Clyde area reaches the length of 10 mm at the end of the first year, 20 mm at the end of the second year, and 25-30 mm in the third year. Their nauplii do not tolerate a salinity below 21-24°/oo (Barnes, 1953), therefore this species is not found in the estuaries of rivers. Evidently, this circumstance also prevents the settlement of B. balanus on the hulls of vessels, because they settle, as a rule, in ports, but the greater part of large ports in the north are located in the estuaries of rivers.

Verruca stroemia was found only on buoys Belyayevskiy and Zhuzhmuyskiy /65
in Onezhskaya guba. On buoy Zhuzhmuyskiy only a few V. stroemia were found setting on mytilids. Their quantity was substantially greater on buoy Belyayevskiy. They were adhering to the metal parts of the buoy and on mytilids at a depth of 3-5 m. The length of the observed specimens was 2-3 mm. According to data by Kuznetsov (1960), a mass occupation of larvae in Onezhskaya guba begins in September. If the V. stroemia individuals found by me had occupied the buoy in September, there is little wonder that their length in November did not exceed 3 mm. Barnes (1958) studying the growth of the species along the coast of Great Britain maintains that the species reaches its maximum size from the beginning of spring to the beginning of winter.

E. F. Gur'yanova (1957) maintains that V. stroemia forms settlements only in calm sea areas and does not tolerate low salinity. Thus, the author explains the absence of V. stroemia in Mezenskaya guba, although it forms dense colonies in the Gorlo of the White Sea. Evidently, the species was not found among foulers on buoys anchored in the Gorlo for the reason that it leaves here at a depth of 10-50 m.

Generally, V. stroemia is relatively seldom found among foulers on hydrotechnical structures. According to an American compilation (Marine Fouling and Its Prevention, 1957*), the species was only observed once on buoys and never on other hydrotechnical structures or vessels.

* Translation date, English to Russian. (Editor's note.)

Mytilus edulis. On the basis of frequency of occurrence (64.4°/o) on buoys of the White Sea, mytilids occupied the second place. Their settlements were limited mainly by the velocity of the current. Therefore, on buoys anchored in the Gorlo and Voronka, the mytilids were not found. On some of the buoys anchored in exposed parts of the sea and its gulfs, the species was either absent (on buoys B and Г in Dvinskaya guba, on buoys Pushlakhotskiy, Bakanskiy, Lyamitskiy, V. Kemskiy, and Zhuzhmuyskiy in Onezhskaya guba, and on buoys of the Chizha River in Mezenskaya guba), or their quantity was limited and their sizes were smaller than in the protected areas of gulfs (table 7).

Table 7

The Quantity and Maximum Size of Mytilus edulis Found on Buoys (under part of the buoys) in the White Sea

Buoys	Number, ind/m²	Biomass, g/m²	Size, mm
Open Parts of the Sea			
A	4,000	30	2
Б	25,200	40	6
Sambaludskiy	11,600	170	11
Avariynyy	200	1	4
Letne-Orlovskiy	1,000	9	1
Yuzhnyy Kemskiy	8,500	15	4
Protected Areas of Gulfs			
Vorob'yevskiy	290,800	2040	8
Tsar'-banka	1,100,000	710	10
Fur'yemskiy	1,800,000	1290	3
Karel'skiy	2,300,000	2200	5
Severodvinskiy (anchor)	20,000	150	18
" No. 1	900	55	15
" No. 2	2,202,200	160	9
" No. 3	364,000	1160	16

On buoys exposed to currents, the mytilids were found in protected places, such as cracks and corners, while on buoys anchored in protected areas of gulfs the species was found all over the surface.

Seldom did mytilids settle on metal parts of buoys; more often did they cover the fibers of hydroids, as though with beads. Blok and Geelen (1958) found that mainly mature specimens are found on mytilid banks. For settlements, however, the mytilids prefer objects covered with fibers because, for development, they require protected niches, as for instance, spaces between the branches of stolons of hydroids. When growing up the mollusks migrate, looking for places suited for living. On buoys that were covered with hydroids, the conditions for forming settlements of mytilids were good, provided the current speed was relatively small, because in such a case they were able to stick to the stolons of hydroids. In cases when the number of mytilids was especially great (1-7.8 million ind/m^2), all of them could not settle on hydroids and they were sticking to one another, forming a soft loose mass.

The size of mytilids on buoys that had been anchored for 6-6 1/2 months reached 18 mm. Such a growth rate is considered exclusively high for the north. According to data by Savilov (1953), the maximum size of one-year old mytilids inhabiting the White Sea reaches 9 mm in the most favorable conditions. In the sublittoral of the East Murmanskiy bereg, the accretion of mytilids is 5.5 mm in a season of growth, but in the littoral the accretion is 3.6 mm (Matveyeva, 1948). It is thought that the living conditions on buoys are exclusively favorable for mytilids, especially in cases when the buoys are placed in protected sections of gulfs, where the churning of water is not intense, where a constant exchange of water occurs and the rivers supply a sufficient amount of nutrients.

Despite the fact that mytilids are rather motile, especially when young (Blok and Geelen, 1958), it is difficult to assume that the buoys had been settled by individuals crawling from the bottom onto the buoys. The chain of buoys is constantly moving along the bottom and therefore its lower portion is clear, as if polished. In addition, if a buoy had been settled by incomers and not by larvae of mollusks, one could find also larger specimens on buoys, as well as other animals. For instance, large stars, univalve mollusks, and other creeping, not swimming, species.

Generally, mytilids are characterized by a rather rapid rate of growth in favorable conditions. In warm waters they grow rapidly. In California they reach 6 mm in two months; and 30 mm in five months

(Graham and Gay, 1945). Even in the German Sea (Mare Germanicum or North Sea, from Europe to Great Britain), the mytilids reach 24-34 mm during the first year of life (Havinga, 1929). In the Black Sea, according to data by Vorob'yev (1938), mytilids reach 40.2 mm in ten months, and 56 mm in 13 months.

It is seen from table 7 that in the exposed portions of the sea, mytilids reach smaller maximum sizes than in protected areas. This can be explained by a smaller quantity of food available in exposed areas, and mainly by rapid water movements and by the churning of water. As demonstrated by E. F. Gur'janova, I. G. Zaks, and P. V. Ushakov (1925), intense churning leads to a decrease in the size of shells.

Nudibranches. Almost half of the buoys were settled by Dendronotus frondosus (Ascanius). Few Coryfella lineata Loven were found on buoy Sambaludskiy, where the former species dominated.

These mollusks occupied all of the surface of buoys except for the algal zone. They are associated with the hydroid Obelia longissima, which is eaten by the former and was numerous on buoys settled by nudibranchiates. Possibly by coincidence, or in connection with competition for nutrients, nudibranches were not found together with caprellids.

The mean quantity of Dendronotus on buoys was 200-400 ind/m^2, the biomass being 20-30 g/m^2, which constitutes 1-2°/₀ of the biomass of foulers. Cases were observed when the quantity of the mollusks reached 1000-3000 ind/m^2, but on the buoy Vorob'yevskiy even 14,000 ind/m^2 at the depth of 4 m, the biomass being 800 g/m^2, which made up about half of the entire biomass of fouling. /67

Generally, nudibranches - the usual components of fouling - are found on various hydrotechnical structures built in the water, on test panels, and, not so often, on vessels, because they are washed off by the moving water. This also explains the absence of nudibranches in the areas of the White Sea which are affected by strong tide currents - namely, in the Gorlo, Voronka, and in Mezenskaya guba.

Bryozoans are rather often found in fouling (33.6°/₀), but their biomass is usually small. Only in one case - on the vane of buoy Sambaludskiy - did the biomass of bryozoans reach 340 g/m^2; usually, the quantity was limited to 0.1-4.0 g/m^2. Sometimes bryozoans (Electra crustulenta) were sticking to the metal surface of buoys or to the shells of barnacles and mytilids, but more often they were found on hydroids (Electra pilosa), whereby their quantity was great.

Owing to their ability to adhere firmly to the surface, the bryozoans were observed both in protected and exposed areas of the White Sea. They were not found only in Gorlo, Voronka, and Mezenskaya guba, probably, for the reason that their larvae could not settle on buoys as a result of great current speeds. E. crustulenta was found in the Severodvinsk area (on buoys No. 3, 11, 13, 14, 17, Yakorniy), but E. pilosa was observed on buoys Belevskiy and Sambaludskiy, and E. pilosa var. dentata (Ellis et Solander) on buoys Vorob'yevskiy and Pur'yemskiy. The presence of E. crustulenta on buoys in Severodvinsk area can be explained by a considerable dilution because, according to M. G. Gostilovskaya (1957), E. crustulenta var. baltica Bord., which was, evidently, found also in my collections, prefers brackish water regions. But, possibly, the occurrence of E. pilosa is associated with the abundance of hydroids on which this species is found.

Harmothoë imbricata was found on the following buoys: Sambaludskiy, V. Kemskiy, Belevskiy, Lyaminskiy, and Yakornyy, i.e. in protected and exposed areas of Onezhskaya guba and Dvinskaya guba. Harmothoë imbricata was the only species observed on the buoys, also singly; their biomass was very small, not exceeding 4 g/m^2. According to data by G. S. Slastnikov (1957), H. imbricata occurs very often in Onezhskaya guba, in most of the biocoenoses, at various depths. M. V. Petrovskaya (1960) records the presence of larvae of this species in plankton along the East Murmanskiy bereg in July and August. According to data by the same author, all the processes of development of H. imbricata, beginning with a fertilized egg to a young benthic form, lasts for 20-25 days.

S. A. Mileykovskiy (1959) notes that H. imbricata, inhabiting various seas, begins to multiply at almost the same water temperature.

Gammarellus homari is found on buoys Lyamitskiy, S. Kedovskiy, Zhuzhmuyskiy, Letne-Orlovskiy, Avariynyy, and Yu. Kemskiy, i.e. in the Gorlo and the exposed portion of Onezhskiy zaliv - in areas crossed by rather rapid currents. The quantity of gammarids on buoys reached 400 ind/m^2, the biomass being 15 g/m^2. These figures have been purposely reduced many times because the gammarids leave buoys that are raised. A. I. Bulycheva (1957) found the species in Kandalakshskiy zaliv, Onezhskaya guba, Mezenskaya guba, and in the basin of the sea, where the species was observed at depths 0-13 m on various types of bottom. The finding of G. homari alone on buoys of all the 95 benthic species of amphipods, noted by A. I. Bulycheva (1957) for the White Sea, allows us to think that this species can swim expertly and hold its place in currents. It is possible that also other species of amphipods had been on the buoys and that they had been washed off or had left the buoys when they were taken out of the water.

Asterias rubens, whose diameter varied from 3 to 15 mm (more often 5-7 mm), was found on buoys Belevskiy, Tsar'-banka, Vorob'yevskiy, Sambuladskiy, No. 1 (in the Severodvinsk area), Pur'yemskiy, and Karel'skiy, i.e. on buoys anchored in Onezhskaya guba, Dvinskaya guba, and Kandalakshskiy zaliv, mainly in the protected areas of gulfs. The stars usually abounded in areas inhabited by small mytilids, which were consumed by the former. Most probably, the larvae of stars had settled on buoys, developing at a rapid rate because, were the stars able to climb the anchor chain of buoys, the sizes of stars found on buoys would have been larger.

Caprella sedovi was found in the following gulfs: Mezenskaya guba (buoy Nes'), Dvinskaya guba (buoys in Unskaya guba), and Onezhskaya guba (buoys Pur'yemskiy and Karel'skiy). They were mainly associated with small mytilids. Thus, on buoy Unskiy 2, many mytilids lived side by side with still numerous caprellids, whereas on the nearby buoy Unskiy 1, on which the number of mytilids was small, also that of the caprellids was small. Especially great numbers of caprellids were found on Pur'yemskiy buoy,on which their number reached 23,000 ind/m^2 at a depth of 1 m, the biomass being 350 g/m^2. The same sample contained a multitude of small mytilids - as many as 2,500,000 ind/m^2 - which contrasted against a small number of hydroids - 50 g/m^2, although it seemed that a large number of caprellids had to be found in places inhabited by hydroids which are used as food by the former. It is possible that the abundance of caprellids in places inhabited by numerous mytilids is associated with the fact that both of the species react similarly to the physical conditions of the medium and cannot tolerate a strong current, for instance, which washes them off the object on which they live.

Anomia squamula was found on buoys Belevskiy, Yu. Kemskiy, V. Kemskiy, and Sambaludskiy, all of which had been anchored along the west coast of Onezhskaya guba. The size of the mollusks ranged from 2 to 4 mm; their forms were either smooth or ribbed, sometimes both together. The number of squamula was small, not more than 4-5 ind. on a buoy.

Lacuna divaricata (=L. fincta) was found singly on the following buoys: Kemskiy, Tsar'-banka, Vorob'yevskiy, Lyamitskiy, Pushlakhotskiy, and Zhuzhmuyskiy.

Saxicava arctica was found on buoy Tsar'-banka. Its length was 2-5 mm, the number reaching 500 ind/m^2 and biomass being 0.1 g/m^2; inside the tube of buoy Vorob'yevskiy the number reached 800 ind/m^2.

All the observed individuals were small, 3-4 mm long, and toothed. They were found among a mass of small mytilids and were evidently held by the byssal fibers of mytilids, as in the case of the dense mytilacean foulings in the Caspian Sea (Zevina, 1958).

Algae were collected from part of the buoys, as the greater part of them were found in ice with the fouling torn off the upper sections. The distribution of algae over the surface of the buoy was as follows. The belt along the water line consisted mainly of diatoms; beneath the belt, green algae prevailed; beginning with the depth of 1-1.5 m, red and brown algae gradually increased.

On buoys found in open water, the algae were observed to a depth of 3-4 m; for instance, on buoy Letne-Orlovskiy the biomass of Antithamnion floccosum was 190 g/m^2 and on buoy Pushlakhotskiy (guba Pushlakhta) it was 380 g/m^2 at the above mentioned depth. Along the water line the biomass of algae reached 1050 g/m^2 (buoy Avariynyy), but at the depth of 1 m it was 1060 g/m^2 (buoy Zhizhginskiy).

The following species of algae were found: /69

	Water line	At the depth of 1 m	At the depth of 3-4 m
Green			
Uraspora penicilliformis	+		
Petalonia fascia	++	+	
Ilea zosterifolia	+		
Entermorpha intestinalis	+		
Parasiolla crispa *			
Red			
Antithamnion floccosum	+	++	++
Polysiphonia nigrescens *			

*Depth data are absent.

	Water line	At the depth of 1 m
Polysiphonia urceolata *		
Ceramium rubrum *		
Brown		
Pylaiella litoralis	+	
Alaria esculenta	+	
Alaria grandifolia		+
Alaria sp. juv.		+
Laminaria saccarina *		
Laminaria sp. juv.	+	
Ectocarpus confervoides	+	
Ectocarpus siliculosus	+	
Scytosifon lomentarius	+	
Chordaria flagelliformis	+	

*Depth data are absent.

The following species were found especially often in various parts of the sea: Urospora penicilliformis, Petalonia fascia, Pylaiella litoralis, which is usually found in marine fouling on vessels (Zvina, 1962), and Ectocarpus confervoides.

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G. B. Zevina

CIRRIPEDIANS IN THE FOULING OF THE BLACK SEA

Abstract

Among Cirripedia inhabiting the Black Sea, Balanus improvisus and B. eburneus are found most frequently. Chthamalus stellatus and Chthamalus depressus occur less frequently, and Verruca spengleri very rarely. Sometimes such warm water forms as B. amphitrite, B. perforatus, B. tintinnabulum, and Lepas anatifera are brought into the Black Sea by the hulls of ships. Here they may even reproduce in summer, but they invariably perish in winter. The penetration of Eliminus modestus into the Black Sea seems quite possible. An identification table of all these species is given.

The cirripedians found in the Black Sea can be divided into several groups.

The first group is composed of the cirripedians that are found everywhere in marine fouling and whose biomass is as a rule great. This group consists of Balanus improvisus and B. eburneus, which live on the hulls of ships, on hydrotechnical structures, stones, cliffs, shells of mollusks, shells of crabs, etc. (Nikitin, 1947; Dolgopol'skaya, 1954, 1959). Morphologically, these species are closely related; they differ only ecologically and, probably, physiologically. B. improvisus inhabits places with stronger currents and turbulence, and it can better survive low water temperature than B. eburneus.

The species of the second group are not so often found and their number is smaller. Chthamalus stellatus and Chthamalus depressus participate in marine fouling only along the water line and in sublittoral belts. I found them among foulers on vessels, but Chthamalus stellatus was found by I. V. Starostin in a well of a water pipe in Novorossiysk. In the littoral zone, Chthamalus depressus lives higher than Chthamalus stellatus. Poli (1791) described both of the species, but beginning with Darwin (1854) Chthamalus depressus was considered to be a variant of Chthamalus stellatus. It was only in 1959 that Utinomi singled out the species again, considering it to be an independent species Chthamalus depressus in the Mediterranean.

Up to the present time, only *Chthamalus stellatus* was considered to inhabit the Black Sea, but in 1960 the British scientist Southward, when examining the collections of the Moscow and Leningrad museums, identified *Chthamalus depressus* (Southward, 1962) in collections of A. S. Zernov, V. V. Chernyavskiy, and mine obtained in various locations of the Black Sea.

To the third group we can assign one species — *Verruca spengleri*, which is seldom found in the Black Sea and whose quantity in fouling is insignificant (Tarasov and Zevina, 1957).

The fourth group consists of thermophilic forms that have been brought into the Black Sea on the hulls of ships. In summer they sometimes multiply here, yielding a new generation; however, in winter they perish. To this group we can assign *Balanus amphitrite hawaiensis*[1], *B. perforatus*, as well as some other species such as *B. amphitrite*, *B. tintinnabulum*, *Lepas anatifera*, etc.

Lastly, the introduction into the Black Sea of *Eliminus modestus* is completely possible. This species traveled by vessels from Australia to the coast of Great Britain during World War II. Here it has not only become established, but is beginning to expand its area. At the present time, *Eliminus modestus* ranges along almost all of the Atlantic coast of Europe. *Eliminus modestus* inhabits brackish waters (with salinity exceeding 10-11°/oo), so that the species can live not only in the Black Sea, but also in the Caspian Sea. *Eliminus modestus* multiplies almost all year round, and in places that are occupied by the species it appears to be a strong rival of the endemic species. /73

A table for all cirripedians, which can be found in marine fouling on vessels and hydrotechnical structures in the Black Sea, is presented below.

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[1] G. B. Zevina and N. I. Tarasov (1954) named the subspecies *Balanus amphitrite communis*, but after a revision made by Utinomi (1960) the subspecies should be called *Balanus amphitrite hawaiensis*.

IDENTIFYING TABLE OF CIRRIPEDIAN SPECIES
IN THE BLACK SEA

1(2) Body consists of pedicle and head. . . . .<u>Lepas anatifera</u> Linnaeus

2(1) Body is devoid of pedicle and is enclosed in a shell of plates

3(4) The plates are asymmetric. . . . .<u>Verruca spengleri</u> Darwin

4(3) The plates are symmetric

5(8) The rostrum has wings, and labrum with a roundish recess in the middle

6(7) Mandible with four teeth and small dentates covering the lower half of the front edge (fig. Б a). Maxilla I has almost a straight front edge (fig. Бб). The bristles on the top of II pair of legs are roughly indented (fig. Бв). . . . <u>Chthamalus stellatus</u> (Poli)

7(6) Mandible with three teeth and the lower corner covered with numerous dentates (fig. A a). Maxilla I with two small recesses on the front edge (fig. A б). The bristles on the top of II pair of legs are roughly indented (fig. Aв). . . . <u>Chthamalus depressus</u> (Poli)

8(5) Rostrum has radii, labrum with angular recess in the middle

9(16) The walls of shell consists of six plates

10(11)Plates, the base of shell and radii are intersected with canals . . . . <u>Balanus tintinnabulum</u> (Linnaeus)

11(10)Radii are not interesected with canals

12(15)Shell is not colored

13(14)Radii are narrow, the outer surface of scutum is without radial delineation. The basal edge of tergum is straight or slightly concave near the carinal side. Maxilla I with simple middle teeth. . . . .<u>Balanus improvisus</u> Darwin

14(13)Radii are wide. Scutum has longitudinal delineations on the outside. The basal edge of tergum is noticeablely concave from the carinal side. Maxilla I with serrate middle teeth. . . . . <u>Balanus eburneus</u> Gould

15(12)Shell is colored

16(17)Shell with longitudinal bands. The top of tergum does not have the shape of bill. . . . .<u>Balanus amphitrite Darwin</u>

17(16)Purple shell, but without clearly pronounced longitudinal bands. The top of tergum is bill-shaped. . .<u>Balanus perforatus</u> Bruguire

18(19)The wall of shell consists of four plates. . . . . <u>Elminius modestus</u> Darwin

Differences between _Chthamalus depressus_ (A)
and _Chthamalus stellatus_ (Б).

а - mandible; б - maxilla; в - bristle of the
last joint of II pair of legs.

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G. B. Zevina and N. I. Tarasov

THE CIRRIPEDIAN FAUNA (CIRRIPEDIA THORACICA) ALONG THE CONTINENTAL COAST OF SOUTHEAST ASIA

Report I

Abstract

Littoral and sublittoral Cirripeds of the seas named below, from the collections of the Zoological Museum of the Moscow University and of the Zoological Institute of the Academy of Sciences of the USSR, were determined.

Only two forms, namely Balanus amphitrite cirratus and B. amphitrite albicostatus, were found in all three seas. The following species are characteristic for the Yellow Sea: Chthamalus challengeri, B. amphitrite krügeri, and B. amphitrite kondakovi. We can mention no characteristic species for the East China Sea; its fauna of the littoral and sublittoral Cirripeds seems to be impoverished fauna of the South China Sea. The South China Sea is more abundant in Cirripeds than the Yellow and East China Seas. There, besides species common with the East China Sea, were recorded Ibla cumingii, Chelonibia patula, Chthamalus malayensis, C. withersi, C. caudatus, Chamaesipho scutelliformis, Tetraclita divisa, and T. sinensis. All in all, we found 16 species (20 forms) in the vicinity of the mainland of these seas. Descriptions and figures are given for the majority of species.

The sea going vessels, including the ones navigating to the south of our waters, are fouled mainly by cirripedians. Such fouling can often be considerable. In order to identify the species of crustaceans that participate in fouling on vessels along the southeast coast of Asia, we processed the collections of the Zoological Museum MGU and of the Zoological Institute of Academy of Sciences of the USSR[1], obtained

[1]We sincerely thank the collaborators of the Zoological Museum and the Zoological Institute for placing at our disposal the material. We express our deep appreciation also to the scientists Dr. Nilsson-Cantell and Dr. Utinomi who forwarded to us their findings. Dr. Utinomi also delivered to us some species of Chthamalus.

from 1910 to 1960 in the littoral and upper sublittoral belts. For the time being we did not investigate the species that inhabit deeper belts, because they are not found in marine fouling on vessels.

The cirripedians inhabiting the littoral and upper sublittoral belts of the area have been rather thoroughly investigated: in the collections that were at our disposal we did not find a single new species.

Altogether, 16 species were determined; however, the number of forms with subspecies and other variations make up 20. This is not much, because Utinomi (1955) has identified 164 species and 30 subspecies (taking into consideration not only shallow water but also deep water forms) for waters surrounding Japan.

Balanus amphitrite cirratus and B. amphitrite albicostatus inhabit the entire coastal waters of southeast Asia: in the Yellow, East China, and in the northern portion of the South China Seas. These two species are most likely to occur in marine fouling on large vessels.

Chthamalus challengeri, Balanus amphitrite krügeri and the related B. amphitrite kondakovi appeared to be typical of the Yellow Sea.

Cirripedian species typical of the shallow water fauna of the East China Sea were not found. A study by Tung-y-Mao and Mao Tselun (1955) lists the following cirripedian species for the Choushan Archipelago of the East China Sea: Lepas anatifera, Octolasmis loveni, Balanus titinnabulum volcano, and Balanus amphitrite communis; these species were not found in our material.

In addition to species that are common in the East China Sea, the northern part of the South China Sea was represented by Ibla cumingii, Chelonibia patula, Chthamalus malayensis, Chthamalus withersi, Chthamalus caudatus, Chamaesiphc scutelliformis, Tetraclita divisa, and T. chinensis. This is undoubtedly caused by the nearness of Indo-Malayan waters with their most copious marine fauna, where Broch had identified 244 species of cirripedians in 1931. However, E. F. Gur'yanova (1959) notes that the tropical fauna of Hainan Island is in less favorable conditions than that of Indo-Malayan waters, because short-term drops in temperature to 6-12°C occur in the Hainan area. Probably, this is the reason that a relatively small number of cirripedian species is found in the northern portion of the South China Sea.

SUPERFAMILY LEPADOMORPHA PILSBRY

Family Scalpellidae

Ibla cumingii Darwin

Ibla cumingii Darwin, 1851; Hoek, 1907; Nilsson-Cantell, 1921; Ibla sibogae Hoek, 1907.

Four morphologically sound specimens (females) of the species were found in the Hainan area (islands Hsiao-chu and Hsin-yang) under stones along the water line during the ebb tide on 21 March 1958.

Distribution: Red Sea, Indian Ocean, Indo-Malayan Archipelago (including New Guinea), SE tip of Honshu, China (Tarasov, 1938).

Mitella mitella (Linnaeus)

Lepas mitella Linnaeus, 1758; Pillicipes mitella Darwin, 1851; Mitella mitella Kruger, 1911a, b; Broch, 1922; Tarasov and Zevina, 1957.

The species was found in collections of the East China (Island P'u-to Shan cP'ut'u-o-Shan) in Choushan Archipelago) and South China (Nao Chou and Hainan) Seas.

Distribution: Indian, West Pacific.

Family Lepadidae

Lepas anserifera Linnaeus

Linnaeus, 1767; Darwin, 1851; Pilsbry, 1907; Tarasov and Zevina, 1957.

Several dozens of large and medium size specimens were obtained from fouling on a boat in the East China Sea (Choushan Archipelago) and from objects cast on the coast of the South China Sea.

Distribution: Tropical and subtropical waters; is brought into the warm boreal and southern waters.

Octolasmis warwickii Gray (fig. 1)

Gray, 1825; Nilsson-Cantell, 1928, 1934; Broch, 1947.

The length of head from 2 to 10 mm, and the pedicel from 2 to 11 mm. Oval-triangular head. The plates occupy about one third of the head (fig. 1, A).

The cavity of the tergum is reached by the upper part of the scutum; the projection of the tergum is directed somewhat above the umbilicus toward the side that is opposite to the carina. The scutum has two branches; the upper branch has the shape of a narrow triangle with

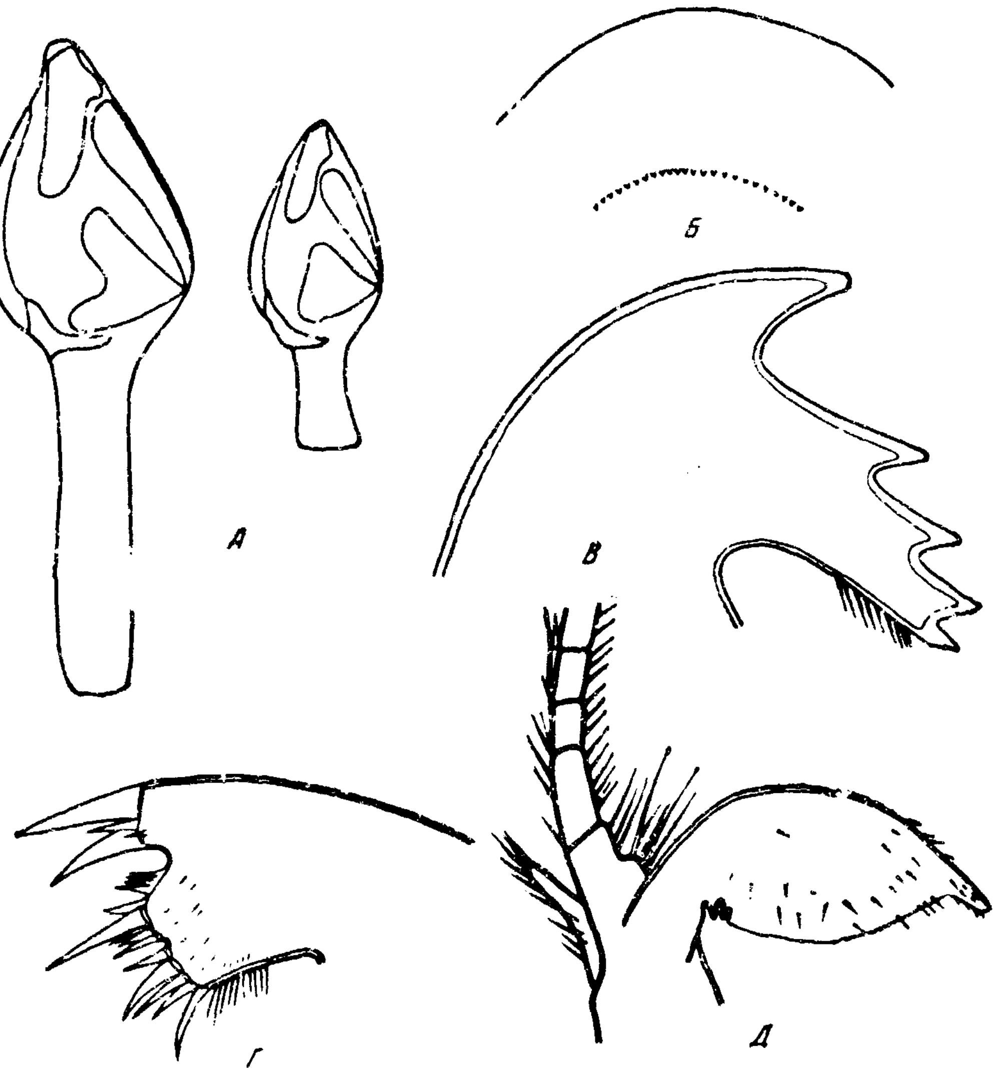

Fig. 1. Octolasmis warwickii, Nao Chau area.

A - external view. x 5; Б - labrum. x 100; B - mandible. x 100; Г - maxilla I. x 100; Д - penis. x 20.

apex projecting downward, but the lower branch has the shape of a wide triangle with apex projecting toward the lower part of the upper branch. The carinal side of the lower branch is concave in large individuals.

In its lower part, the carina branches so that the upper section enters the lower as a wedge. The lower section has two forks.

The length of pedicels varies, the length ranging from one-half to one and one-half the length of the head.

Labrum has a multitude of small teeth (fig. 1, Б). Palps are oval, slightly sharpened at the end. Their upper part is covered with bristles of medium size, which form long bristles in the end.

Mandibles have four teeth; the lower corner is stretched in the form of the fifth small tooth. The surfaces of lower teeth and the lower corner appear to have doubled indentations (fig. 1, B).

Maxillae I have clearly pronounced cavities in the upper one-third, below two large and one small teeth. A group of tiny teeth lie in the lower part of the cavity. Four teeth of medium size and six or seven small teeth lie beneath the cavity (fig. 1, Г).

Maxillae II are broad-lobed and rather densely covered by bristles. /79
The number of joints in the legs of a specimen whose head is 8 mm long are as follows:

I	II	III	IV	V	VI
6 8	— 12	12 13	12 13	12 12	12 12
6 7	10 12	— 13	12 13	12 12	11 12

The tail appendages are one-segmented, lying somewhat above the basal joint of the VI pair of legs, covered by spines, which are especially dense and long at the end (fig. 1, Д).

The penis is somewhat thick, covered by scattered short bristles (fig. 1, Д).

The species was found three times in our material: 1) on <u>Limulus</u> at Nao Chou Island on 11 December 1958; 2) at the same island on 10 December 1958, the object was pointed out; 3) Cape T'e-chan, Chan-chien, on 29 October 1958, on a crab.

Distribution: from the South China Sea to the Indian Ocean, i.e. Indo-Pacific.

SUPERFAMILY BALANOMORPHA

Family Chthamalidae

Chthamalus challengeri Hoek (fig. 2)

Hoek, 1883; Pilsbry, 1926; Nilsson-Cantell, 1921, 1927; Hiro, 1932, 1939a; Tarasov and Zevina, 1957.

Great similarity with Ch. dalli, inhabiting the continental coast of the Sea of Japan and to the north of it (Tarasov and Zevina, 1951). The scutum and tergum in the latter species is extremely variable, so that the variations are reminiscent of those of Ch. challengeri. Usually, however, the tergum of Ch. challengeri lies lower (fig. 2, Б) than that of Ch. dalli, and the valves of operculum are thicker (fig, 2, A, Б). The variability of valves is so great that it is often difficult to determine which of the species has been found. It is possible that later we shall discover the intermediate forms.

Similarity between the mouths of the two species is complete, except that the serrate part of mandibles in Ch. challengeri is slightly shorter. However, Hiro (1932) described such variations of mandibles and maxillae in the species, that this can in no way be considered as a legible characteristic. The parts of the mouth of Ch. challengeri are presented in fig. 2, B - Ж.

Hiro (1935) states that Ch. dalli differs from Ch. challengeri by a more compressed form, by lower parietal ribs and a simple commissure between the scutum and tergum, as well as by differences in the shapes of scutum and tergum.

The strong teeth in the lower part of the serrate bristles on the ends of II pair of legs, which were mentioned by Pilsbry (1916), were not observed in our specimens. We observed only serrate bristles on the ends of II pair of legs of exactly the same type as in the Ch. dalli (see fig. 106 д, Tarasov and Zevina, 1957).

Masses of Ch. challengeri were found in the collection obtained from the littoral belt of the Yellow Sea (Lüta and Ch'ing Tao).

Distribution: Japanese, Indo-China and Malayan waters. Nilsson-Cantell (1938) points out that the species lives in the Indian Ocean and the Red Sea.

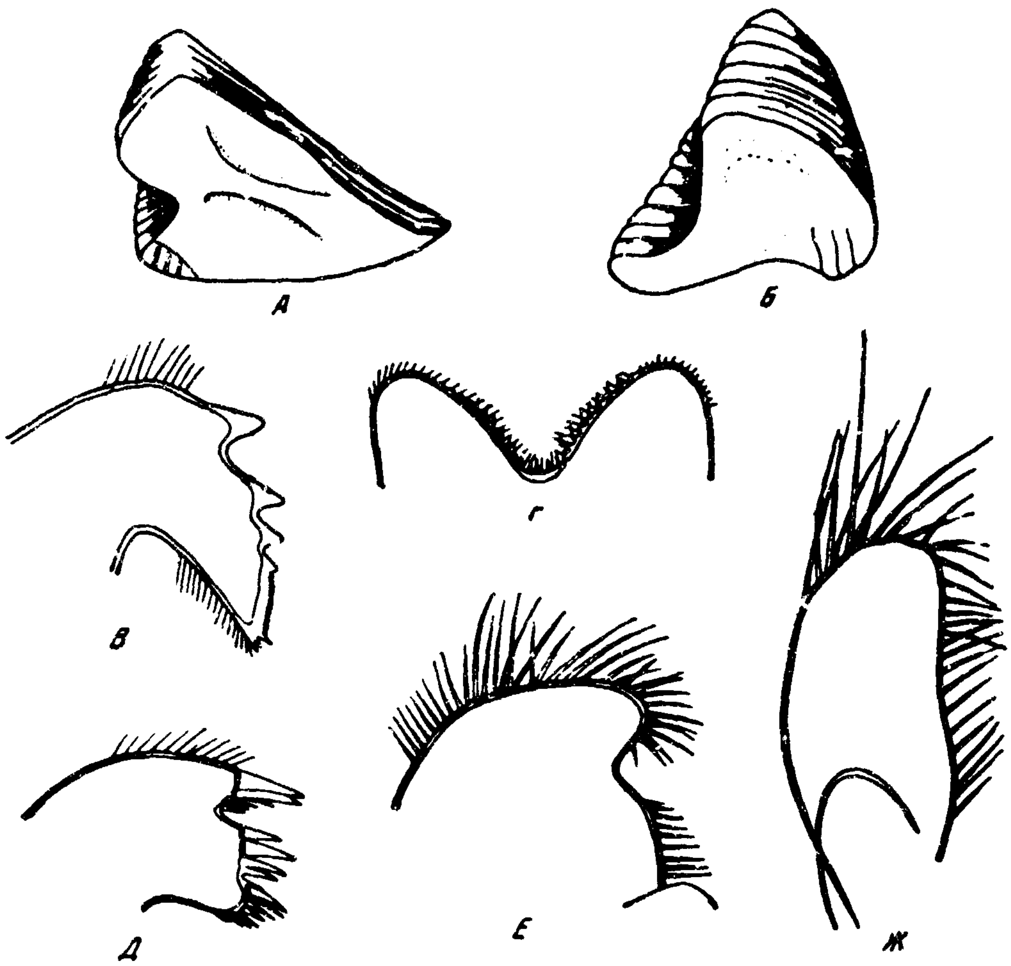

Fig. 2. Chthamalus challengeri, Lüta area.

A - inside of scutum. x 20; Б - inside of tergum. x 20; B - mandible. x 100; Г - labrum. x 80; Д - maxilla I. x 100; E - maxilla II. x 100; Ж - palp. x 200.

Chthamalus malayensis Pilsbry (fig. 3)

Ch. malayensis Pilsbry, 1916; Broch, 1931; Nilsson-Cantell, 1938; Hiro, 1939b; Utinomi, 1954.

Ch. moro Pilsbry, 1916; Broch, 1931; Hiro, 1937a, b.

Ch. challengeri f. krakatauensis Broch, 1931.

Flat shells of white or pale brown-gray color. In some specimens the lower edge is very indented and surrounded by brown color. The inside of the shell is white. The mantle is dark. The commissures between the plates are simple.

The scuta and terga are white, smooth, as if polished, and thick. A small concavity is on the outside of the scutum, which extends along the closing edge of the upper half of the plate. In the basitergal corner of the plate lies a noticeable tubercle. The adductor is without crown. The condyle crown and stria are well developed. A small, yet deep, scar of lateral depression is observed. The scar of the adductor is pronounced (fig. 3, A).

Terga are broad (fig. 3, Б). The condyle crown is triangular, has a large condyle stria. On the scar of the depressor muscle are four convex and rather long crowns.

Labrum is concave, covered with thin hair; the numerous teeth are quite visible (fig. 3, B). The mandible has four teeth (fig. 3, Д).

Maxilla I has two large teeth, beneath which are four small teeth, /81
reaching into a rather deep cavity. Beneath the cavity four to five pairs of teeth of medium size are seen, then comes one more noticeable cavity under which a group of thin teeth is seen (fig. 3, E). Maxilla II is rounded, almost ball-shaped, with a small cavity in front dividing two parts. Both of the parts are covered by bristles which are especially long on the upper part (fig. 3, Г). The numbers of joints in the legs are as follows:

I	II	III	IV	V	VI
6 8	5 6	12 14	15 17	16 17	17 19

I and II pairs of legs have a dark pigmentation; III-VI pairs have a dark pigmentation only along the frontal edge of each joint and in the upper rear corner. A few thick bristles lie on the end joints of both branches of the II pair of legs; the upper half of bristles is covered by two rows of large teeth, reminiscent of grains. Two very large teeth stand out in the middle of the bristles (fig. 3, Ж).

Pilsbry (1916), describing the species, points out that the II pair of legs does not have dented bristles. Utinomi (1954), however, reports that the individuals of this species collected in the waters of Taiwan

Fig. 3. Chthamalus malayensis, San-ya (Hainan).

A - inside of scutum. x 15; Б - inside of tergum. x 15; В - labrum. x 100; Г - maxilla II. x 100; Д - mandible. x 100; E - maxilla I. x 100; Ж - bristle of the top of II pair of legs. x 700.

have two sizable teeth beneath the indented upper part of bristle on /82
the second pair of legs. The VI pair of legs has three pairs of long and one (fourth) pair of very short bristles on the front part of the middle joints.

The greatest width of penis is at the base from where it narrows toward the end, which is covered by scattered bristles.

This species was found on the cliffs and rocky beaches of Taiwan (Sanya, Mayachnyy*, and Hsin-ching islands) and on Balanus tintinnabulum and Tetraclita squasmosa viridis. In May we found specimens containing eggs in the pallial recess.

Distribution: northeastern part of the Indian Ocean, Indo-Malayan Archipelago, Philippines, Palao and Taiwan, i.e. in the Indian West Pacific area.

Chthamalus withersi Pilsbry (fig. 4)

Pilsbry, 1916; Nilsson-Cantell, 1921, 1930, 1931; Hiro, 1937a.

The shells are depressed, the carino-rostral diameter being 2-8 mm. The roofs are wide with straight tops. The commissures between the scutum and tergum and between the other plates are simple.

The cases are brown; new individuals have darker cases with white spots or bands stretching from the top of the plates to the base.

The scutum has a dark brown color with a white band whose width varies from one individual to the other; it extends along the tergal edge; besides, a very narrow and short, sometimes hardly notice ble, band extends from the top to the upper concluding edge. The condyle is not convex; its apex lies almost in the central part of the tergal edge, from where the sides of the condyle become lower in upward and downward direction. The crest of the adductor is weakly pronounced. The scar of the lateral depressor is clearly pronounced. The scar of the adductor has an oval form and is rather large. According to Pilsbry (1916), the scutum of Ch. withersi does not have the scars of the adductor and depressor muscles; however, in the species we had, the scars were well pronounced (fig. 4, A).

The tergum has a dark brown color with a white band on the scutal side, which is sometimes very wide, occupying half of the plate or more. On the inner side, as in the case of the scutum, one can see dotted depressions; sometimes they are also found on the outside. The tergum has a roundish triangular form, narrowing abruptly toward the lower part. The tergum is not, however, so narrow as described by Pilsbry (1916); its form is rather reminiscent of that of Ch. malayensis Pilsbry. Several ribs are on the scar of the muscle of the depressor. The basal end is almost straight (fig. 4, Б).

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*A Russianized name, not identified with NIS Gazetteer. Translator.

The labrum has a small cavity and almost 20 to 25 rather sizable teeth along its edge; five to seven middle teeth are markedly high and very large, so that they have the form of brief, sharp sticks. Palps are rectangular with slightly roundish free corners.

The mandible has three teeth, beneath which five to six teeth of average size are seen; then follow three rather large teeth lying on the lower corner. Sometimes the upper side of the lower (third) tooth is indented (fig. 4, Г).

Maxilla I has two indentations dividing the front edge into three uneven parts. The upper part has two large teeth and several small ones; the middle part has five to six teeth of medium size, and the lower part, which projects a little forward, has six to eight thin teeth of medium size (fig. 4, B).

Maxilla II has two recesses, the parts of plates are not clearly pronounced. The number of joints in the legs of a specimen of medium size is as follows:

I	II	III	IV	V	VI
6 8	6 7	16 17	19 19	21 22	23 23
6 8	6 7	16 17	18 19	22 23	23 23

The bristles of the upper joints of the II pair of legs are serrate, as in Ch. challengeri. The central joints of the VI pair of legs each have three pairs of bristles.

The penis is long - not shorter than the VI pair of legs - narrowing gradually toward the end.

On the basis of the structure of mandibles and the presence of three pairs of bristles on the joints of the VI pair of legs, our specimens are reminiscent of Ch. withersi Pilsbry, differing from Ch. malayensis, which was also described by Pilsbry (1916); but the form of scutum and tergum, the presence of clearly noticeable scars of the lateral depressor and adductor on the scutum are reminiscent of Ch. malayensis Pilsbry.

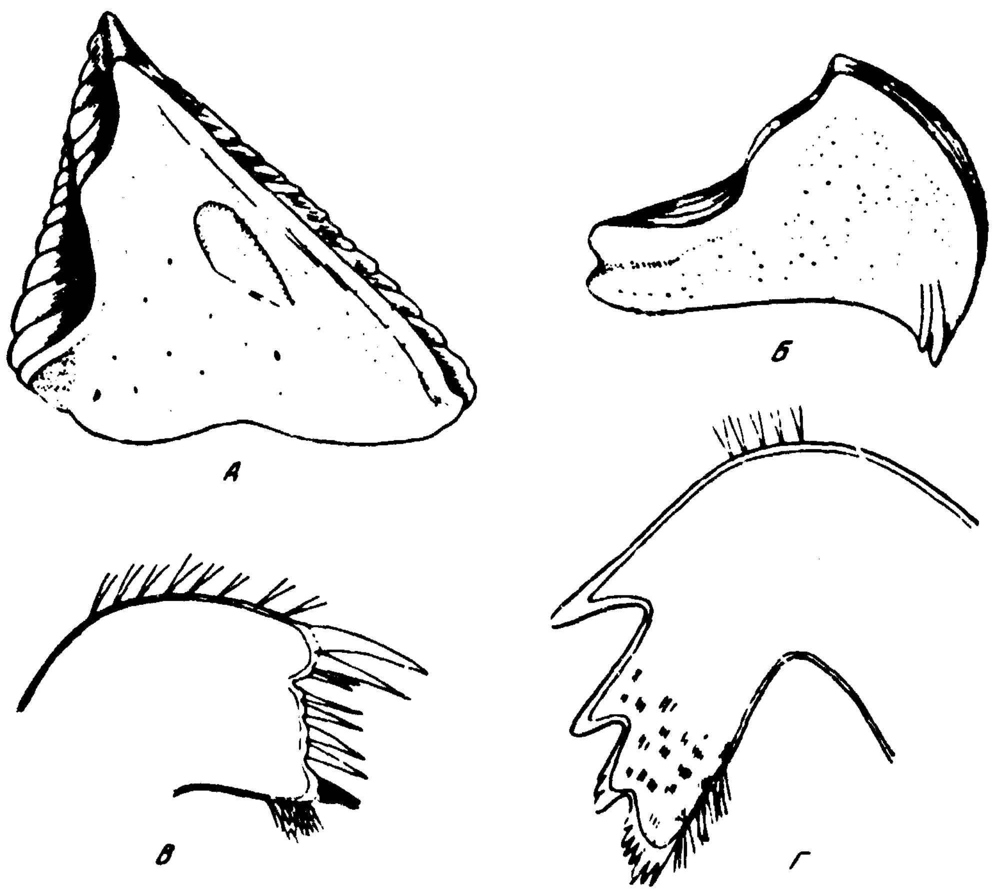

Fig. 4. Chthamalus withersi, San-ya (Hainan).

A - scutum from inside. x 40; Б - tergum from inside. x 40; B - maxilla. x 200; Г - mandi- ble. x 200.

A large quantity of this species was found on Hainan and Chan-chien, usually in the shells of Balanus amphitrite albicostatus, but sometimes on piers or on trunks of mangroves. /84

Chthamalus caudatus Pilsbry (fig. 5)

Chthamalus caudatus Pilsbry, 1916; Nilsson-Cantell, 1921, 1930; Hiro, 1937a.

The carino-rostral diameter is 4-7 mm. The color is yellow-brown; the upper and lateral edges of plates are lighter. The outside of the lateral (parietal) plates is covered with undulating lines marking the growth. The lower edges of the plates are also undulating. The inside of the plates is smooth. The radii are weakly pronounced. The roofs are well developed, especially on the rostrum and carina. The wings are covered with crosswise striae (lines of growth), on which, in turn, one can see a weakly pronounced longitudinal hatching.

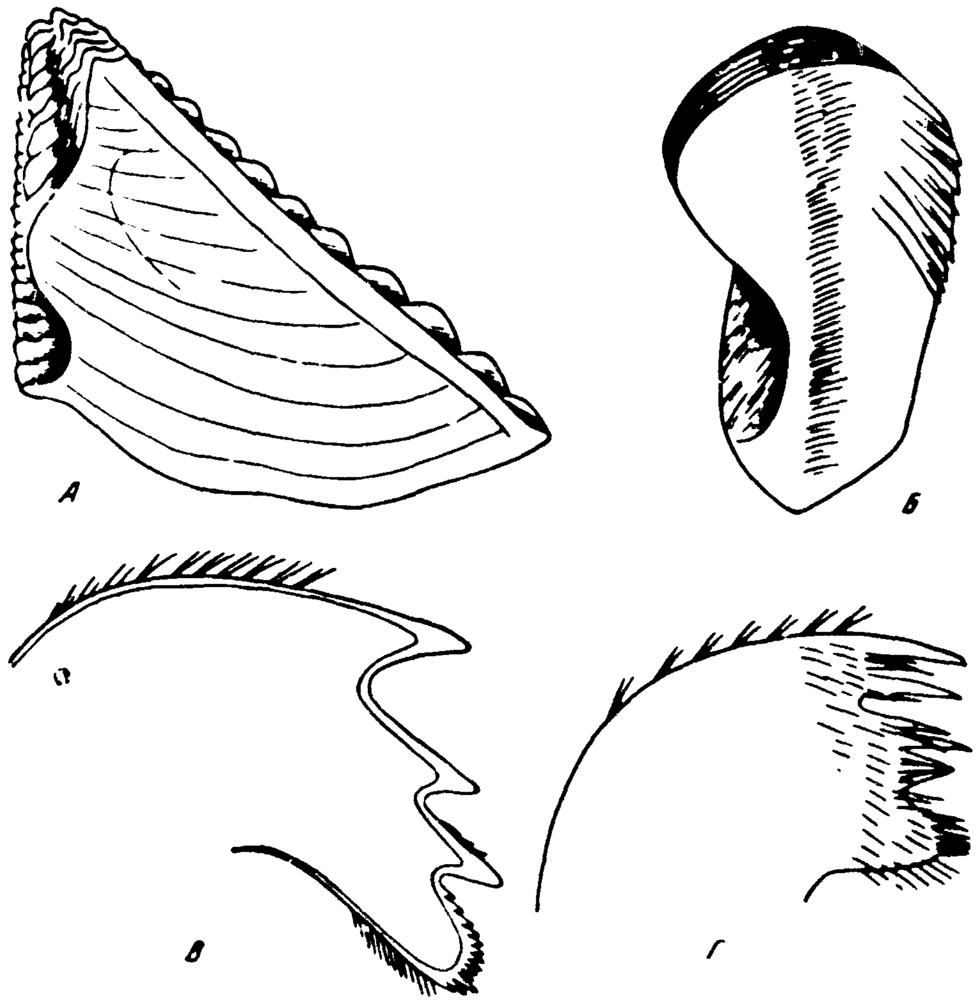

Fig. 5. Chthamalus caudatus, Hainan.

A - scutum from inside x 40; Б - tergum from inside x 40;
B - mandible x 200; Г - maxilla I. x 200.

The outer surface of the scutum is thinly lineated with perpendicular lines of growth. The condyle is roundish and well pronounced. The adductor does not have a crest but the scar of the adductor is noticeable. The lower edge of the scutum is tortuous (fig. 5, A). The tergum is narrow, with well developed crests for the fastening of the depressor muscle (fig. 5, Б). The labrum with a row of rather strong teeth is ornamented with hairs. The palps are roundish on the front end. The mandible has three teeth and an indented lower corner. One of the two hidden specimens had crenulations on the upper side of its third tooth (fig. 5, B). Maxilla I has two indentations on the frontal end, separating three groups of teeth (fig. 5, Г). Maxilla II has a rounded rear part and a concave front part. The upper rear part is covered with long bristles, but on the front side are brief thick bristles. The number of joints of legs is as follows:

I	II	III	IV	V	VI
5 7	7 8	9 11	12 13	13 14	14 14

Individual fur-trimmed bristles grow on the end of I-II pairs of legs; identical bristles grow on the middle joints of the III pair of legs. The tail appendages have the length of almost 3/4 of the VI pair of legs; they consist of 20 to 21 joints, each of which has several bristles.

Four specimens of this species were found on a boulder in the Hainan area (San-ya, Eastern Island, cliffy and stony littoral, upper horizon) and a rather great number of specimens was found on boulders at Hsin-ching on 2 May 1958.

Distribution: Philippines, Sumatra, Pisang, Arakavui (Palao), i.e. in the Indo-Malayan waters.

<u>Chamaesipho scutelliformis</u> Darwin

(fig. 6 and 7)

<u>Chamaesipho scutelliformis</u> Darwin, 1854; Fischer, 1884.

Shell with a roundish base consists of a roof (two terga and two scuta), a narrow trapezoidal rostrum, a twice wider carina, and two, still wider, lateral plates. All of the four lateral (parietal) plates are devoid of pores (canals). No radii exist, but all the four plates have wings that are especially noticeable at the carina.

Nearer to the base, the parietal plates have rough and irregular ribs on the outside. Therefore, the lower end of the shell has a web-footed or fimbriate form. Four undulated "commissures" of the shell are most peculiar: two on the carina and two on the lateral plates. These

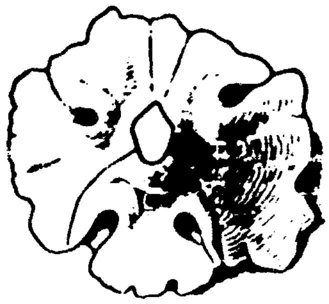

Fig. 6. Chamaesipho scu-telliformis, Nao chou area.

General view of the shell from outside. x 10 (drawing by N. N. Kondakov).

"commissures" begin at the upper part of the shell (a little below the opening in the roof) with oval openings or, as Darwin puts it, tubes. These openings in the lateral plates are somewhat larger than in the carina. The long axes of the openings are arranged in radial directions.

The openings and their continuations are marked already on young specimens in the form of undulating commissures; soon they become well pronounced from the outside, and especially from the inside of the shell (fig. 6), creating a misleading impression that the latter consists of six, and not four, plates. However, four straight actual commissures extend to the opening in the roof, which become barely noticeable with age. Darwin assumes that such a form of the shell makes it firm despite its thin and transparent walls. /86

The roof valves are typical of the family Chthamalidae (fig. 7, A, Б, [illegible] also the crest of the adductor is well pronounced in the scu-[illegible]

[illegible] is deeply indented; in the indentations lie several well pronounced teeth (fig. 7, Д) [illegible] not just hairs, as Darwin writes. The

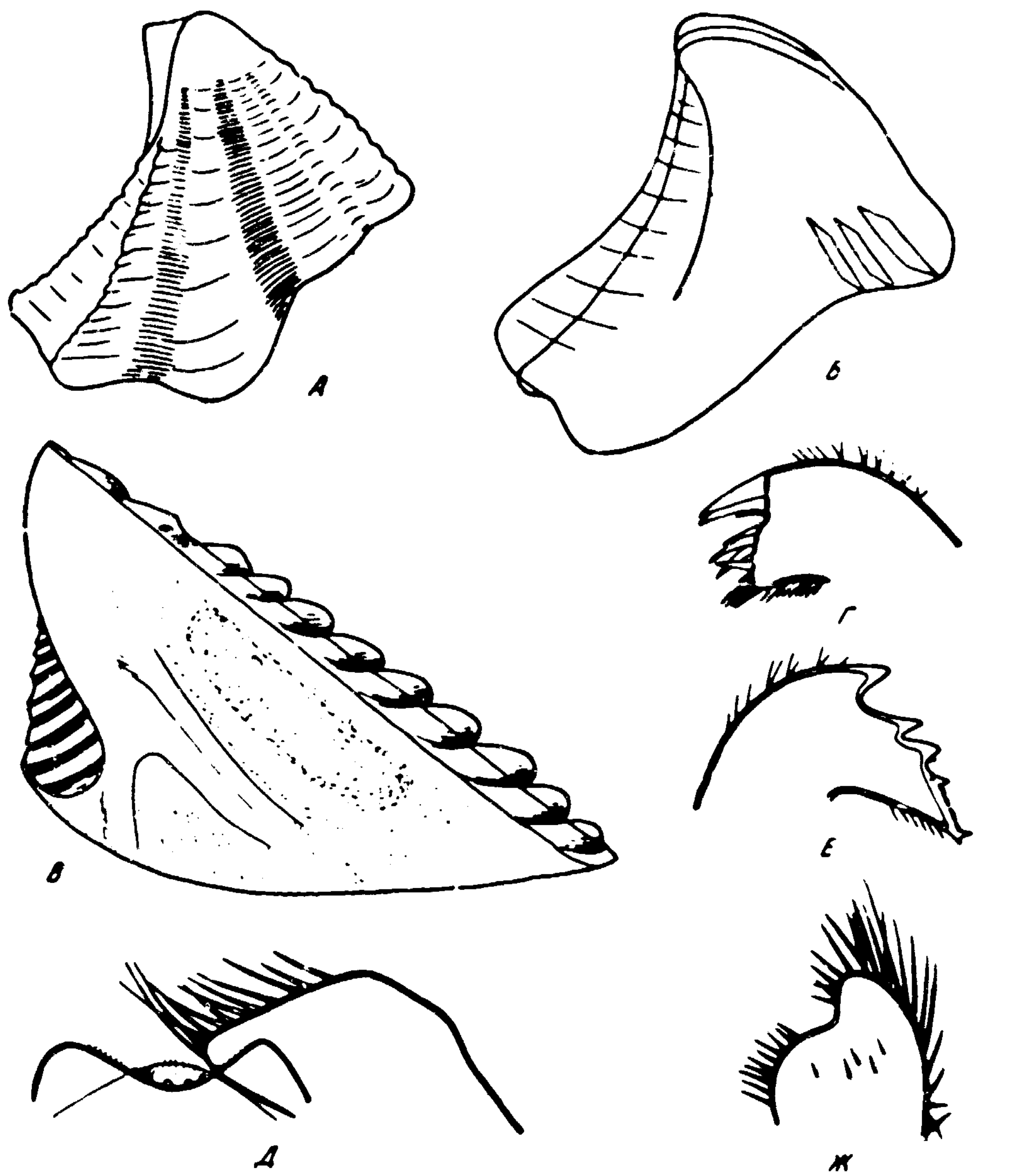

Fig. 7. Chamaesipho scutelliformis, Nao chou area.

А - tergum from outside. x 100; Б - tergum from inside. x 100; В - scutum from inside. x 100; Г - maxilla I. x 200; Д - labrum and palp x 200; E - mandible x 200; Ж - maxilla II. x 200.

bristles at the end of the palps are long. The mandible has four teeth, beneath which extends a spiny edge with one or two teeth in the lower corner (fig. 7, E). Maxilla I has two large upper teeth, several smaller ones in the middle, and on the lower angle a group of thin teeth that are still shorter (fig. 7, Г). Maxilla II has two clearly pronounced sections (fig. 7, Ж). The number of joints of legs is as follows:

I		II		III		IV		V		VI	
5	6	5	5	9	11	14	14	14	14	15	15

The branches of the first pair of legs are of unequal length, as in the case of the II pair in which the inequality is smaller. The bristles of the last and basal joints of the pairs of legs are pinnate, which, of course, makes possible the catching of minute peridinians, chrysomonadins, coccolithophorids, and other nannoplankton.

Darwin found "developed" larvae even in small specimens, which was not observed by us, possibly, for the reason that the samples had been collected during the winter monsoon.

Small specimens of the species (about 3 mm in diameter and 2 mm in height) were observed in rather great numbers on plates of Mitella mitella obtained at Nao chou and Hainan (Mayachnyy* Island) and on boulders at Hainan (San-ya, Easter Island, also called: Niu-Hsin Tao), and at Hsin-ch'ing.

Darwin, who first described the species, found it on Mitella "probably of the China seas" and named it "scutelliformis", because the shell was reminiscent of the contours of shells of the flat sea urchin Scutellum. Fischer points out that Ch. scutelliformis was found in the area of the Pacific group of the New Caledonia islands.

Family Balanidae

Balanus tintinnabulum tintinnabulum (Linnaeus)

(fig. 8)

Lepas tintinnabulum Linnaeus, 1758.

Balanus tintinnabulum var. communis Darwin, 1854; Balanus tintinnabulum tintinnabulum Pilsbry, 1916; Hiro, 1939b; Tarasov and Zevina, 1957.

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*A Russianized name, not identified with the NIS Gazetteer. Translator.

The length of shells that were at our disposal reached 50 mm, the maximum height being 45 mm. The walls of the shells were densely covered by hydroids, bryozoans, and sponges. At places, the parietal plates had a dark purple color; at other places they were almost dark green with light longitudinal bands. The walls of the shells were smooth. The radii were wide with cross hatchings. Short (not reaching the inside wall) longitudinal septa branch off the outer wall of the shells; the apices of the septa were covered with numerous crosswise runners. The base was white, smooth inside.

The inside of the scutum and tergum were covered with a dark purple mantle. The inside of the roof plates was white, at places rosy-violet. The scutum was wide (fig. 8, Б). The growth lines were clearly discernible on the outside of the scutum; sometimes, a weak longitudinal contour was observed, The condyle was well pronounced on the inner side of the plate above the middle line. The scars of the adductor and lateral depressor were clearly visible.

The tergum is broad and has a triangular form, with a narrow and long spur (fig. 8, A).

Labrum has two or three teeth on each side of the indentation. The palps have thinly indented bristles. The mandible has four to six teeth, sometimes with a double lower corner. Pilsbry (1916) has presented a drawing of the mandible with four teeth. Sometimes a specimen had various numbers of teeth on the mandibles of the right and
left sides. Maxilla I has almost straight front part, on which a pair /88
of large teeth lie; beneath them one can see six pairs of thin middle teeth; then again a pair of long teeth and several pairs of small teeth at the lower corner are seen. The maxilla II has a longitudinal shape and is densely covered with thin indented bristles. The numbers of joints in legs are as follows:

I	II	III	IV	V	VI
19 23	16 22	13 14	44 44	46 47	49 50

The lower joints in I and II pairs of legs are very wide, whereas the upper joints become abruptly narrow. The narrowing of the III pair is uniform. The middle joints of the VI pair have three large and one small pair of bristles. The length of penis equals that of the VI pair of legs. A small tubercle lies at the base of the penis.

In our case, this form was found on the coastal cliffs of Hainan (20-21 April 1958, Nan-wang-chou; 20 April 1958, Mayachnyy (lighthouse) Island, and 3 December 1959, West Island ⌈Hsi-mei-chou⌉).

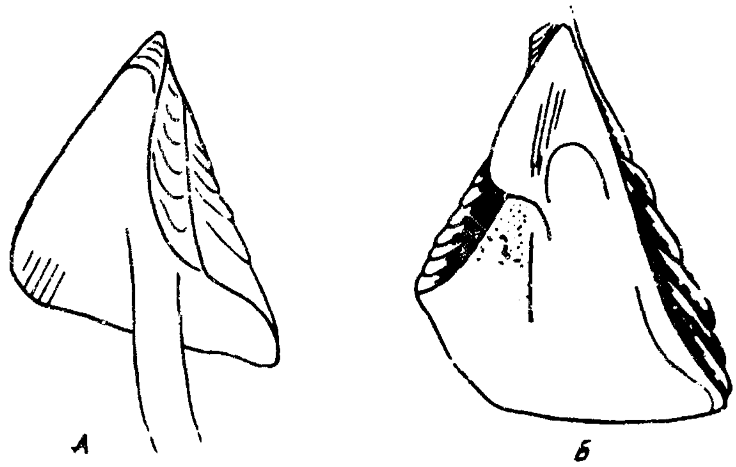

Fig. 8. Balanus tintinnabulum tintinnabulum, Hsing-ts'un (Nan-wang-chou).

A - inside of tergum. x 3; Б - inside of scutum. x 3.

Distribution: found on the hulls of ships from the most diverse seas, including the seas of the USSR. Hiro (1939b) found this form in the South China Sea and on Taiwan.

Balanus tintinnabulum occator Darwin (fig. 9)

Balanus tintinnabulum occator Darwin, 1854; Pilsbry, 1916; Hiro, 1939b.

Size: length from 15 to 25 mm; height reaching 22 mm. Shells are violet-purple, with thin longitudinal lines and wide light crosswise lines intersecting the plates. The lower part of the shell is covered by sharp teeth directed downward. In smaller specimens the teeth are correspondingly larger. The radii are wide, with narrow dark and light bands running crosswise.

The scutum is rather narrow. On the outside it seems that the growth lines are assembled in folds (fig. 9, A). A well developed condyle and scars of the adductor and depressor muscles are seen inside (fig. 9, Б). The lower basal edge is not smooth, but folded. The tergum has the form of a narrow triangle with a bill-shaped apex. The spur is long and narrow (fig. 9, B). Labrum has two teeth along the sides of the indentations. Palps are covered by thin indented bristles. Mandible has five teeth with a double lower corner. Maxilla I has an almost straight front edge. On the top is a pair of large teeth; then follows a small cavity and below it are several pairs of medium size teeth, further one can see again a small cavity, beneath it is a pair of large teeth, but in the lower corner are several pairs of small thin teeth. Maxilla II consists of two sections — the upper

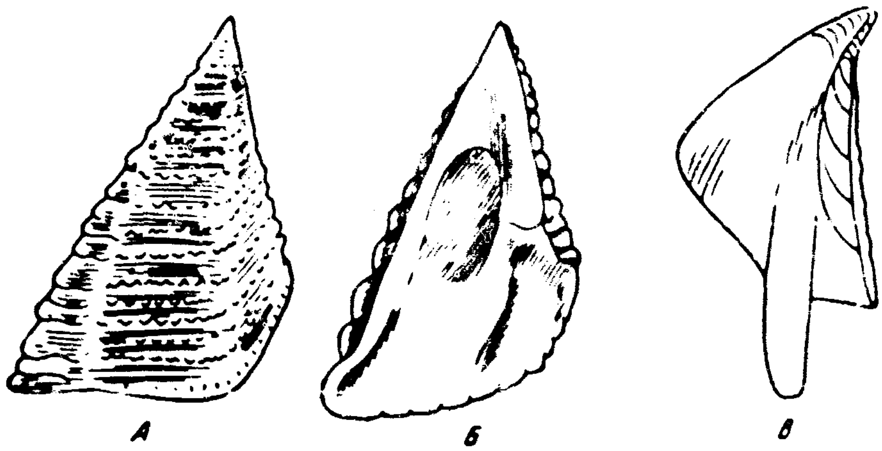

Fig. 9. Balanus tintinnabulum occator, Hsing-ts'un (Nan-wang-chou).

A - outside of scutum. x 4; Б - inside of scutum. x 4; B - inside of tergum. x 4.

one, which is rather long and narrow, and the lower one, which is reminiscent of a small ball. Both of the sections are densely covered with lightly indented bristles. The numbers of joints in legs are as follows:

I	II	III	IV	V	VI
13 17	10 13	9 10	32 29	22 32	— 33

The middle joints of the VI pair of legs have two large pairs and one small pair of bristles.

The length of penis equals the VI pair of legs; a small horn is at its base.

This form was found in the Hainan area (Nan-wang-chou) on coastal cliffs on 20 April 1958, together with B. tintinnabulum tintinnabulum.

Distribution: Indo-Pacific, Indian Ocean, and Taiwan. According to Kolosvary (1950), this is a typical fouler on coral reefs. Utinomi (1954) found this form on Takara-Jima (Lat. 29° N) and Taiwan (25°), while the related Balanus tintinnabulum volcano was not found south of Lat. 31° N.

Balanus amphitrite cirratus Darwin (fig. 10)

Balanus amphitrite cirratus Darwin, 1854; Weltner, 1897; Gruvel, 1905; Nilsson-Cantell, 1921; Hiro, 1938; Tarasov and Zevina, 1957.

The shell has a conic form, its color being violet-brown and having at times almost a bright hue with light and dark longitudinal and crosswise bands, which are either weakly or clearly pronounced. The radii are wide with tapered tops; sometimes dark crosswise bands are seen on the radii. The color of the shells is variable, the probable reason for it being the illumination of the biotope.

The scutum has the form of an acute angle, on its outside are well pronounced growth lines and violet longitudinal bands. The violet color is seen within the shell.

The condyle is well developed, reaching almost to the middle of the edge of the plate. The crest of the adductor is uniformly curved and rather long. The scar of the lateral depressor is clearly noticeable and extended in height. The scar of the adductor is not so clearly noticeable (fig. 10, A). The tergum has a rather long and sharp spur. The growth lines and violet spots are seen on the outside. The basal edge on the sides of the spur is straight. Several rather long crests are seen in the spot where the depressor muscle is fastened (fig. 10, Б). The labrum has two to four teeth on each side of the indentations. The mandible has three large and two smaller teeth; the latter are indented (fig. 10, Г). Maxilla I has a projecting lower edge (fig. 10, B). The first pair of legs has one branch which is longer than the other by several joints, the outer branch has greatly extended joints. The II pair of legs has one branch that is slightly longer than the other; the joints are rather convex, strewn with small indentations along the inner edge; fascicles of spines lie under the long bristles on the inner lateral side (fig. 10, Д). The III pair of legs has large teeth on the convex sides of the joints, fascicles of spines lie along the upper edge; three to four rather long spines lie /91

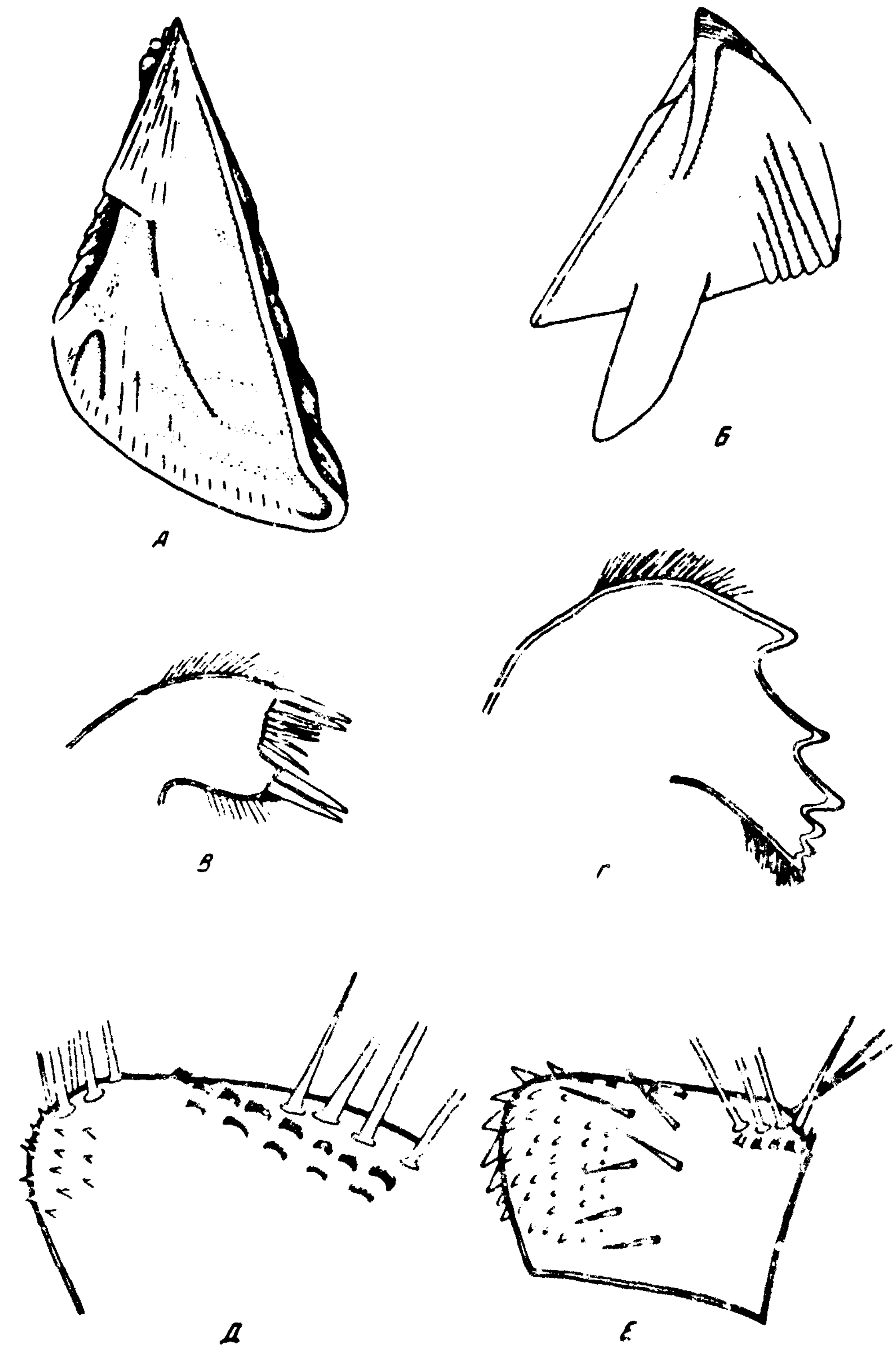

Fig. 10. Balanus amphitrite cirratus, Chan-chien (South China Sea).

A - inside of scutum. x 20; Б - inside of tergum. x 20; B - maxilla I. x 200; Г - mandible. x 80; Д - middle joint of the II pair of legs. x 300; E - middle joint of the III pair of legs. x 300.

in the upper rear corner of the joint (fig. 10, E). The length of the last pairs of legs is equal.

Large quantities of the species were found in the Lüta, Yang-t'ai, Ch'ing-tao, Chan-chien, and Hainan areas, i.e. along the entire coast of China. The species often lives on the shells of mollusks and crabs.

Distribution: along the coast of China, the Philippines, Indo-Malayan Archipelago, and Australia.

<u>Balanus amphitrite albicostatus</u> Pilsbry (fig. 11)

<u>Balanus amphitrite albicostatus</u> Pilsbry, 1916; Nilsson-Cantell, 1921, 1938; Hiro, 1937b, 1938; Tarasov and Zevina, 1957.

The shells have a conic shape and thick walls with wide rhomboidal openings. The color of the shells is dark purple with white bands; some of the shells are noticeably corroded and pale as a result. When looking from above on the commissure line between two scuta, one can clearly see its tortuous form in the lower half. The radii and wings are wide, with slightly tapered tops. In uncorroded specimens the scutum has a wide violet band on the outside and violet spots inside, as is also the case of the tergum. The condyle is very clearly pronounced reaching — or sometimes extending below — the middle of the tergal edge. The adductor crest is clearly convex, but not very long. The cavities of the adductor and lateral depressor are clearly noticeable. The upper half of the inner side of the scutum and tergum is hatched with brief ribs running downward (fig. 11, A).

The tergum has a short and relatively wide spur, constituting about 1/3 of the basal edge. The basal edge lies obliquely with respect to the spur. Four to five crests of the depressor muscle project clearly outward; the basal edge projects slightly in the spot where the crests end. Between this projection and the spur one can, on the straight edge, sometimes find small protrusions of tiny ribs covering the inside of the tergum (fig. 11, Б). The parietal plates contain canals with partitions in the upper part.

The labrum has two to three clearly pronounced teeth and pubescence along the sides of indentations (fig. 11, E). The form of palps is almost quadrangular, with dense pubescence; a row of long bristles extends in a slightly oblique direction along the lower edge; some of the bristles (the long and short ones) are serrate. Mandible has three large teeth and two smaller teeth; the second — fifth teeth are double or double indented; the lower corner is sometimes roundish, at other times indented (fig. 11, Г). Maxilla I has a somewhat projecting lower third of the front edge, on which grow two large teeth with several

Fig. 11. Balanus amphitrite albicostatus, T'e-chan (South China Sea).

A - inside of scutum. x 10; Б - inside of tergum. x 10; B - maxilla I. x 80; Г - mandible . x 80; Д - bristles at the end of joints in the III pair of legs. x 500; E - labrum. x 80.

smaller ones beneath the former (fig. 11, B). Maxilla II is noticeably extended in length, is densely tomentose, part of the bristles covering it is serrate. The numbers of joints in legs are as follows:

I	II	III	IV	V	VI
13 19	14 18	16 19	30 33	33 33	34 35

I —II pairs have projecting joints. The joints of I-III pairs of legs have serrate bristles. The III pair of legs is often covered with three to seven very large teeth sitting on one side. Not infrequently, part of the specimens of this species, which had been obtained simultaneously, had bristles with teeth on the III pair of legs, but the other part of the specimens did not have such bristles (fig. 11, Д). The middle joints of the VI pair of legs have four pairs of bristles (according to Pilsbry, 1916, five pairs).

The penis is somewhat shorter than the VI pair of legs, is ring-shaped, narrowing toward the end; its narrow section is covered with hair. The number of fascicles of bristles is especially great at the end of the penis.

The species was abundant in the littoral belt and on stones and cliffs along the entire China coast. This species has also been obtained in the Lüta, Yang-t'ai, Ch'ing-tao, Choushan Archipelago, Chan-chien, and Hainan areas.

Distribution: the coasts of China, Japan, and the Mediterranean Sea (found by Kolosvary). The species was found on vessels arriving from Japan and Australia (Allen, 1953).

<u>Balanus amphitrite krügeri</u> Nilsson-Cantell

(fig. 12, A - Б)

Nilsson-Cantell, 1932.

The size of the barnacles varies from 3 to 18 mm if the carino-rostral diameter is considered. The shells are brown-red with white longitudinal bands; sometimes the bands are dark, at other times completely bright.

The outside of the scutum is slightly concave, and has a wide and dark longitudinal band nearer to the tergal margin. The band is also seen from inside. The pronounced condyle lies above the middle of the plate, which contrasts with a statement by Nilsson-Cantell (1932). The crest of the adductor is well developed, but it is not very long. The scar of the lateral depressor is noticeable (fig. 12, Б). The tergum is curved and has a rather narrow spur, which narrows downward. Deep cavities lie along the sides of the spur. The crests fastening the depressor are long; their number ranges from five to six. The inside surface of the tergum is papillate above the crests; the papillae reach the upper part of the spur (fig. 12, A).

The labrum has four clearly marked teeth on each side of indentation. The mandible has five teeth. The third, fourth, and fifth teeth have additional smaller teeth. Maxilla I has two large upper teeth sitting on a small projection; beneath it lie four pairs of medium-size teeth, and further below it lie two large teeth on a rather pronounced projection; beneath the projection are several small teeth decreasing downward. The numbers of joints in legs are as follows:

I	II	III	IV	V	VI
14 19	15 15	16 17	26 25	36 34	36 36

The II pair of legs has branches whose length varies. The III pair /94
of legs has large teeth on the inside of the upper joints. The middle joints of the VI pair of legs have three pairs of long bristles and one short one.

The samples examined by us had been obtained from T'ien-ching (T'ang-ku, South «Dam» Head, the river side, 6 km from the coast. Littoral on 13 June 1957) and from Yang-t'ai (fouling from a cutter, thrown on the coast on 29 June 1957).

Distribution: Japan and China.

<u>Balanus amphitrite kondakovi</u> Tarasov et Zevina

Tarasov and Zevina, 1957.

The species was found on buoys in front of the entrance to Port Yingkou, i.e. in the estuary of Taliao Ho-k'ou (Liao Ho-k'ou), in the Liao-tung gulf of the Yellow Sea.

Balanus amaryllis Darwin

Darwin, 1854; Hoek, 1913; Pilsbry, 1916; Nilsson-Cantell, 1921; Stubbings, 1961.

The shells have a conical form, the carino-rostral diameter being 24-30 mm. The plates have red-yellow color and they are hatched with dark-red vertical bands of different width. The base is white. The radii are narrow, their tops are obliquely truncated.

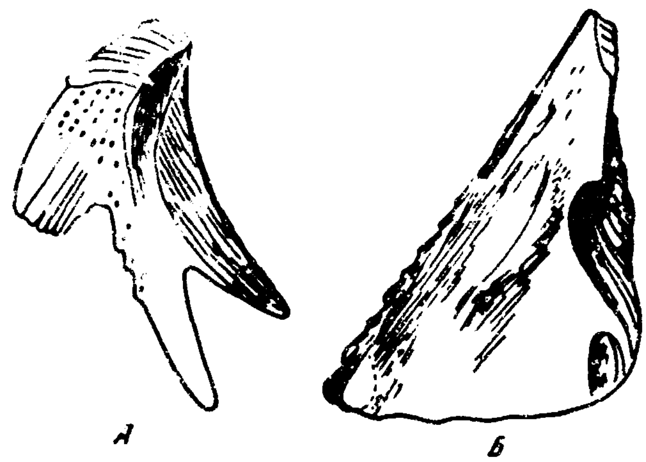

Fig. 12. Balanus amphitrite krügeri, T'ien-ching, T'ang-ku.

A - inside of tergum. x 10; б - inside of scutum. x 10.

The outside of the scutum is clearly delineated crosswise and in longitudinal direction. The condyle does not project beyond the tergal edge; the crest of the adductor is found only in the upper half. The scars of the adductor and depressor are well-marked.

The outside of the tergum has weak longitudinal lines. The top of the tergum has a bill-shaped curvature. The spur is rather long and narrow, slightly widening downward and being obliquely truncated.

The labrum has three clearly noticeable teeth on either side of indentation. The mandible has three large upper teeth and two tubercles replacing the lower teeth. The projecting lower 1/4 of the front edge of maxilla I projects forward; on the front edge are two large teeth; beneath them lies a brush of tiny dents, which gradually decrease. Maxilla II is elongated and densely covered with bristles. The numbers of joints in legs are as follows:

I	II	III	IV	V	VI
17 23	17 20	22 23	44 49	56 60	59 60

The I-III pairs of legs have more or less curved joints; the VI pair of legs has narrow joints with two pairs of long bristles, in the base of which lie several pairs of short bristles; the rear half of the joints is covered with numerous spines. The penis has several clusters of bristles on its end and scattered bristles on the remaining surface.

Two specimens were found on 10 November 1958 at Chan-chien (on reef Ernan) in the littoral belt, two specimens were found on 5 May 1958 at Hsing-ts'in on Pinna, the depth was not indicated, and three specimens were found in the Ch'ing-tao area at a depth of 8-32 mm.

Distribution: Indo-Malayan Archipelago, south Japan and India, east and northeast Australia, China, Ceylon, Zanzibar, Persian Gulf, i.e. the Indo-West Pacific.

Chelonibia patula (Ranzani)

Coronula patula Ranzani, 1818; Darwin, 1854; Pilsbry, 1916.

The species was found in the South China Sea (Chan-chien, Cape Tech-zhan'sh. Littoral on 29 November 1958). The length of one specimen was 12 mm, height 2.5 mm; four individuals 2-4 mm long were sitting on the former. Regrettably, the note did not indicate the object which was occupied by the *Chelonibia*. This species is usually found on crabs or *Limulus*.

Distribution: Mediterranean Sea, tropical and subtropical waters along the Atlantic coast, Australia, and Japan.

Tetraclita squamosa viridis Darwin

Tetraclita porosa viridis Darwin, 1854; Borradaile, 1900; Krüger, 1911a, b; Nilsson-Cantell, 1921, 1930, 1931.

Tetraclita squamosa Pilsbry, 1916.

Tetraclita squamosa viridis Broch, 1922, 1931; Hiro, 1937a; Utinomi, 1954.

The species was abundant in the East China Sea (Choushan Archipelago) and in the South China Sea (on the littoral at Choushan).

Distribution: Indo-West Pacific; indications of existence in West Africa, and in the Panama area.

Tetraclita squamosa japonica Pilsbry, 1916

Tetraclita porosa var. *rubescens* Weltner, 1897.

Tetraclita porosa var. *nigrescens* Krüger, 1911a, b.

Tetraclita squamosa japonica Pilsbry, 1916; Hiro, 1932, 1937a; Tarasov and Zevina, 1957; Utinomi, 1958.

Tetraclita porosa japonica Nilsson-Cantell, 1927, 1931, 1932.

The large specimens examined by us corresponded entirely to the decription by Pilsbry (1916), whereas the small specimens, which were often found in the same samples and sticking to the large individuals, differed from the large ones. The younger and smaller the individual, the more it had teeth on the jointed surface of the scutum; the smaller the number of rows of pores within the parietal plates, the more noticeable and larger the hair on the outside along the growth lines of the plates, as well as on the scutum and tergum. The large specimens, in which the carino-rostral diameter exceeded 20 mm, are typical of *T. squamosa japonica*, but the small individuals correspond to the *T. porosa perfecta* described by Nilsson-Cantell (1931). It is possible that the last subspecies represents in actuality young *T. squamosa japonica* that live in very favorable conditions, and therefore reach rapidly large size and perfect form.

The teeth on the jointed surface of the scutum grow, evidently, with the development of individuals beginning from the peak of the plate; therefore four to five teeth remain in the lower part of the jointed surface in mature individuals, while 10 to 12 teeth are on the scuta of young individuals.

Tetraclita squamosa japaonica thrive on the littoral of P'ut'o-shan (island) in the Choushan Archipelago, in the East China Sea on 16-18 November 1958.

Distribution: Coast of Japan, Korea, and China.

Tetraclita divisa Nilsson-Cantell (fig. 13)

Nilsson-Cantell, 1921; Hiro, 1939b.

Fig. 13. Tetraclita divisa, Hainan.

A - inside of tergum, x 30; Б - inside of scutum. x 30; B - mandible. x 100; Г - labrum. x 100; Д - maxilla II. x 100; E - maxilla I. x 100.

The color of shells is pale violet-rose; the plates have pronounced longitudinal folds and bristles, which are especially well discernible in small individuals. The plates are strewn with pores arranged in three to four rows. The walls of shells are very thin. The radii are wide. The base is webbed. Hiro (1939b) found individuals with thin calcareous base, but also in such a case the central section of the base was webbed.

The scutum is very much extended. Its middle part is concave from the outside and somewhat convex from the inside. The adductor edge is not clearly visible (fig. 13, Б).

The tergum has a triangular form with a small roundish spur; five to six crests are well pronounced in the place where the depressor is fastened (fig. 13, A).

The labrum is slightly concave, has two to three tubercles on each side and, in addition, rather dense bristles (fig. 13, Г). Palps are covered with pronounced feather-shaped bristles and groups of short bristles.

The mandible has four teeth; the second and third teeth each have a small supplementary tooth, but the fourth tooth has two to three supplementary teeth; the lower corner is thin and long, several small teeth are under the corner (fig. 13, B). Maxilla I has a clearly pronounced indentation beneath the two long upper teeth (fig. 13, E). Maxilla II consists of a small convex lower part with several bristles and has many bristles on the upper part (fig. 13, Д). The numbers of joints in the legs are as follows:

I	II	III	IV	V	VI
5 8	6 6	4 6	8 -	7 8	8 9
- -	5 6	4 6	6 7	9 11	9 10

The branches of the I pair of legs are not of the same length. The bristles on the II and III pairs of legs are pinnate.

Four average (to 8 mm long) and numerous small (about 2 mm long) individuals were found on a boulder (6 December 1959, Hainan, Sanya, East Island or Tung-mei-chou. Littoral).

Distribution: Sumatra, Java, and Taiwan.

Tetraclita (Tetraclitella) chinensis

(Nilsson-Cantel) (fig. 14)

Tetraclita purpurascens chinensis Nilsson-Cantell, 1921; Hiro, 1939b.

Tetraclita purpurascens nipponensis Hiro, 1931, 1937a.

Tetraclita chinensis Utinomi, 1954.

The carino-rostral diameter of the individuals ranged from 6 to 12 mm.

The shells were grayish. The outside of the parietal plates was covered with deep longitudinal wrinkles; the plates did not have holes, as presented by Nilsson-Cantell (1921) and Hiro (1939b); it is possible that the holes were absent for the reason that the shells of our samples were tightly welded together with one another, and many of them were covered by calcareous algae. In younger individuals the lower edges of the shells were extremely tortuous. The walls of the shells and roofs were covered with clearly noticeable rows of bristles, which had not been pointed out by the earlier investigators. The walls of the shells had numerous pores.

The scutum had a deep longitudinal cavity on the outside and a convex lower part. The adductor crest was long and curved in the middle at an obtuse angle (fig. 14, A). The tergum was small and had a short spur, with six long clearly pronounced crests in the place where the depressor was fastened (fig. 14, Б). The labrum had a shallow cavity, on each side of which one could see three to four rather large teeth. The upper part of the labrum had a dense pubescent trimming (fig. 14, B). Palps had an oval form. In the front of the palps, one could observe long bristles; the top of the bristles was covered by several shorter bristles, many of which were pinnate. On the bottom one could see several tiny spines arranged in rows (fig. 14, E). The mandible had four teeth, three lower ones of which had supplementary teeth. The lower edge had the form of an acute long tooth; the space between the latter and the large fourth tooth was richly indented; sometimes, a tiny fifth tooth could be detected beneath the fourth tooth (fig. 14, Ж).

Maxilla I has two large upper teeth; the small teeth lie in the cavity beneath the two large teeth, several small and medium-size teeth lie beneath the cavity; then follow two rather large teeth, beneath which one can see five small teeth (fig. 14, Г). Maxilla II has two blades.

On the tergal side of the upper blade grow several pinnate bristles (fig. 14, Д). The numbers of joints in the legs (in an individual whose carino-rostral diameter was 12 mm) are as follows:

I	II	III	IV	V	VI
6 12	7 7	6 7	12 13	13 16	16 16

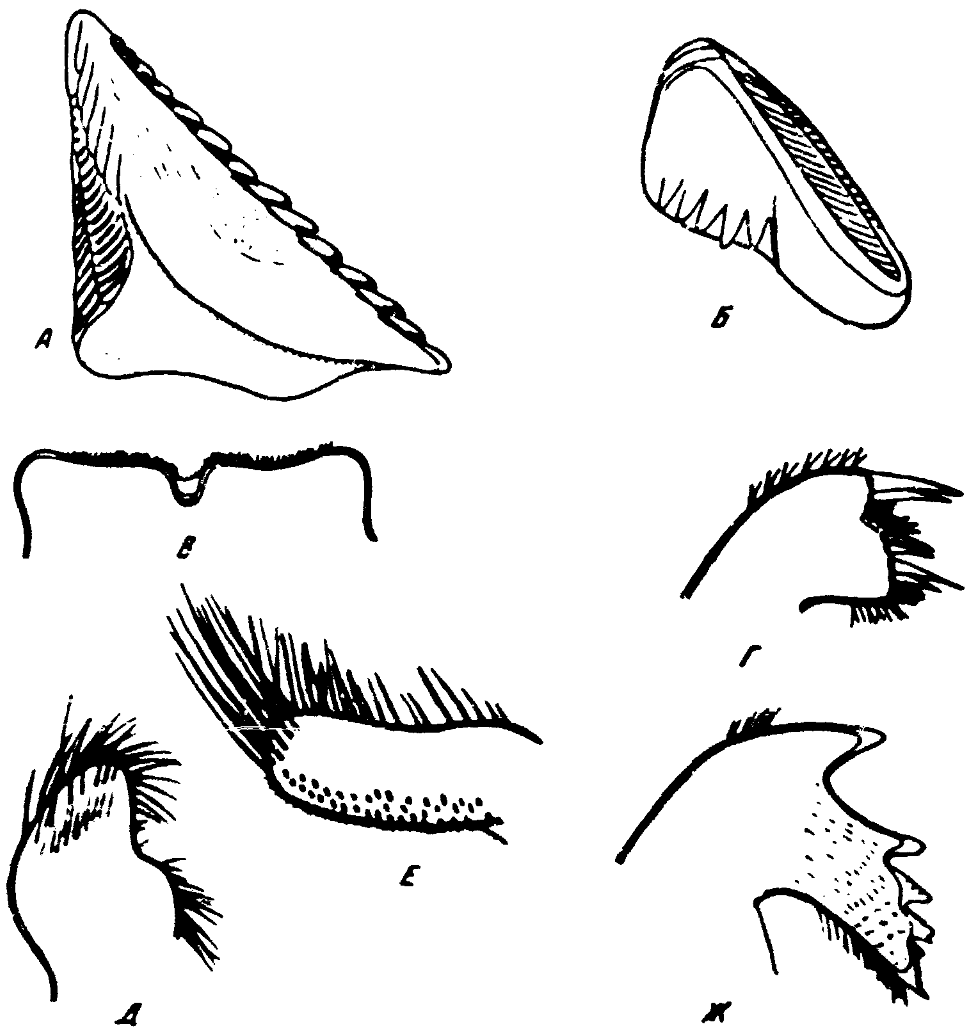

Fig. 14. Tetraclita chinensis, Hsing-ts'un.

А - inside of scutum. x 15; Б - inside of tergum. x 15; В - labrum. x 100; Г - maxilla I. x 100; Д - maxilla II. x 100; E - palp. x 100; Ж - mandible. x 100.

The internal branch of the I pair of legs is almost twice as long as the external branch. Pinnate bristles grow on the external branches of the I pair and on both of the branches of the II and III pairs of legs. Three pairs of bristles cover the middle joints of the VI pair of legs. The penis is longer than the VI pair of legs; bristles grow on its end. About 10 specimens were found holding to Balanus tintinnabulum on 20 April 1958 at Hsing-ts'un (Hainan).

Distribution: Hsiang-kang, Taiwan, and south Japan (as far north as Sagami-wan).

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I. V. Starostin

MARINE FOULING IN TECHNICAL WATER CONDUITS IN OUR SOUTHERN SEAS AND SOME OF THE METHODS IN FIGHTING THEM

Abstract

The following forms of mass occurrence were recorded in the fouling of technical water conduits in the southern seas of the USSR: Lamellibranchiata (Mytilus galloprovincialis, Mytilaster lineatus, Dreissena polymorpha; Crustacea — Balanus improvisus, B. eburneus; Hydrozoa — Cordylophora caspia, Perigonimus megas).

With open systems of water intake the development of the forms listed above depends mainly on the local hydrological conditions. With closed systems and a very heavy pollution of sea water by industrial wastes no fouling whatever was observed in the water piping.

The use of sea water for the cooling of industrial and power establishments involves more often than not the appearance of marine fouling within the water supply system. A mass development of fouling diminishes the capacity of the water supply system, often causing complications in the operation of the system.

Because of the death or washing of organisms off the walls of pipes a "biological refuse" is formed, which clogs the filters and other parts of the cooling system, creating a constant threat of obstruction in the water supply. In such cases the pressure in the system rises, becoming critical at times, which may cause a breakdown in the system.

Because of this, the filters of the blast and Martin furnaces in metallurgic plants must be frequently cleaned, but the turbo-generators in heating electrical plants must be stopped in order to clean the pipe plates and oil coolers, whereby in periods when masses of foulers are torn off the walls of pipes the operation need be repeated several times a day. Great inconvenience and difficulties arise when the condensation pipes are cleaned of the solid shells of mollusks, the removal of which is associated with an increase in the corrosion of nonferrous metals. The fouling in technical water pipes may impede the automation of a development.

The marine fouling in technical water conduits of the most diverse undertakings not only creates constant complications in the operation, the elimination of which is difficult, but also creates considerable losses, resulting from nonproductive waste of work, leading to excessive use of fuel and electrical energy.

All of what has been said about the negative role of marine fouling in technical water conduits pertains also to other hydrotechnical structures in our southern seas.

The fouling of water pipes results from the fact that the larvae of some sedentary benthic animals occupy and propagate at a rapid rate in closed operating water supply systems. This biocoenosis of animal foulers can be considered as a special case of benthic lithophilous and littoral-philous biocoenoses, which live on artificial bottoms in conditions that are different from natural conditions, which leads to a pauperization of their species composition. The character of man's activity can affect considerably the formation and development of fouling. Thus, with the development of navigation, some animal foulers have expanded the area inhabited by them to such a degree that they have become cosmopolitan forms: meanwhile, the pollution of certain /102 sea areas by industrial wastes cannot only pauperize the fouling, but lead to a complete extermination of the foulers.

At the present time about 20 species of animal macrofoulers[1] have been identified in the fouling on technical water conduits in our southern seas, whereby the main species belong to the Mediterranean-Atlantic fauna, which have at various times and by various means penetrated the Black Sea and later the Sea of Azov and the Caspian Sea. The wide propagation of the species and their mass development in brackish-water seas has been furthered, first of all, by their great euryhaline character and by the absence of predators and competitors in the seas.

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[1]N. I. Tarasov (1959, 1961) lists only five species of foulers in our southern seas, namely: Balanus improvisus, B. eburneus, Mytilus galloprovincialis, Mytilaster lineatus, and Cordylophora caspia. Besides, the author does not consider it useful to include Dreissena polymorpha and Mercierella enigmatica. This statement is, however, applicable only with respect to marine fouling on vessels, because Dreissena polymorpha, Mercierella enigmatica, Perigonimus megas, a number of bryozoans, and other invertebrates are mass forms in some of the water conduits.

It is seen from Table 1 that the occurrence of the foulers has become almost uniform in all the southern seas.

Table 1

Occurrence of the Mediterranean-Atlantic Invertebrates in Marine Fouling in Technical Water Conduits in Our Southern Seas

Animal	Seas*		
	Black Sea	Sea of Azov	Caspian Sea
COELENTERATA			
Perigonimus megas	+	+	+
POLYCHAETA			
Mercierella enigmatica.	+	+	+
MOLLUSCA			
Mytilus galloprovincialis	+	+	-
Mytilaster lineatus	+	+	+
CRUSTACEA			
Balanus improvisus.	+	+	+
B. eburneus	+	+	+
Chthamalus stellatus.	+	-	-
BRYOZOA			
Bowerbankia imbricata	+	+	+
Electra crustulenta	+	+	+

*No data on fouling in technical water conduits in the Aral Sea exist.

Of local fauna, only dreissens and cordylophores are found in the fouling of the Azov and Caspian Seas in large numbers, thus constituting a considerable portion of the fouling biomass.

The biocoenoses of fouling in technical water conduits are, as a rule, saturated with numerous motile organisms from unicellular forms to fishes inclusively. The biocoenosis of fouling of water conduits is colonized by motile animals, which are casually brought by water currents in larval or mature forms of development; the major portion of the foulers only pass through the water pipes, but some become clogged among foulers. As a result, a large mass of motile animals accumulates, establishing a rather complex mutual relationship with the biocoenosis of fouling.

Small motile organisms in marine fouling cannot cause complications in the operation of a cooling system, but many large forms of crustaceans are capable of hampering the operation of the system. For example, the Rhithropanopeus harrissii tridentatus, when appearing en masse in water pipes, may clog the filters of a cooling system. At the same time, the crabs and nudibranchs (Stiliger bellulus) consume large quantities of hydroidal polyps (Perigonimus megas) in one of the water conduits in the Sea of Azov, which, undoubtedly, leads to a decrease in their total biomass (Turpayeva, in this collection of papers).

The mass forms of foulers can belong to one or several groups, forming the most diverse combinations, which are determined by purely local conditions. Therefore, in order to forecast the development of fouling and work out effective means to fight it in technical water conduits that are built or planned, it is important to know not only the species composition of fouling in a given water basin, but also the conditions affecting the formation of marine fouling in various sections of a given water basin for a long time period (not less than a year). In addition to its practical significance, the results of such investigations are of great theoretical interest.

FOULING IN WATER CONDUITS IN THE BLACK SEA

The composition of fouling in the Black Sea and the ecology of its forms have been rather completely discussed in papers by V. P. Vorob'yev (1938), S. B. Grinbart (1937a, b, 1938, 1948), S. B. Grinbart and G. I. Konoplev (1948), S. A. Zernov (1913), V. N. Nikitin (1947), I. V. Sharonov (1952), and etc.

The main forms of Black Sea foulers are Mytilus galloprovincialis, Mytilaster lineatus, Balanus improvisus, B. eburneus. Depending on local conditions, organisms of secondary significance are added to them, such as sea anemones, polychaetes, golden stars, bryozoans, and etc.

According to Grinbart (1938, 1948), the fouling on hydrotechnical structures in Oddeskiy zaliv consists mainly of mytilids (to 4 kg/m^2)

and barnacles (to 0.13 kg/m^2). Membranipora denticulata is almost always found on the valves of mytilids. The biomass of fouling on test panels reached 6 kg/m^2 in 16 months, with mytilids constituting the main mass (4.5 kg).

The species composition in Sevastopol'skaya bukhta is considerably richer than in Odesskiy zaliv. According to Dolgopol'skaya (1954), here we have to add oysters, sea anemones, polychaetes, bryozoans, etc. to the main forms of fouling - namely, mytilids and barnacles. Depending on the time of employing the panels, the total weight of marine fouling fluctuates from 58 to 107 kg/m^2 in a year.

According to observations by Nikitin (1947), the fouling biomass on a barge that had been staying immobile in Sevastopol'skaya bukhta reached 97.5 kg/m^2 in five years.

It is seen from Table 2 that the settlement of barnacle larvae takes place throughout the year, the most intense occupation being in May-June, the least intense one in August-September. The settling of bryozoan larvae occurs from April to December, the peak being reached in June. The greatest numbers of sea anemones were found in April-July, the smallest in September-November. The settling of oysters occurred from June through September, but that of polychaetes occurred only in June and August. The hydroids formed settlements in spring (March-May) and in winter (September-January). /104

The settlement of larvae in Gelendshikskaya bukhta occurs somewhat differently (Table 3).

With the most important fouler - the barnacle - two periods of settlement are observed: a brief spring period and a weak summer period which continues, on the average, five months, the maximum intensity being 66,000 ind/m^2 (per decade (months?)) (Nikitin and Turpayeva, 1958). The settlement by mytilids (mainly Mytilus) also takes place in two periods; however, in contrast to Sevastopol'skaya bukhta, the intensity of occupation during the spring period is incomparably weaker than in the lengthy (seven months) summer-autumn period. The greatest intensity of settlement of mytilids was observed in June 1960 - namely, 25,000 ind/m^2 (Petukhova, in this collection of papers). In the Gelendshik area, bryozoans Lepralia have the longest period of settlement. Their larvae are absent only in February-March. The maximum numbers of larvae are observed in June-July; especially great numbers of bryozoans (to 32-33,000 ind/m^2) were observed in July 1955 and 1956. The other foulers in the given area are insignificant.

Table 2

The Number of Fouling Organisms that Monthly Occupy 1 m^2 of Surface of Iron Panels Submerged in Sevastopol'skaya bukhta in 1949-1950 (according to data by Dolgopol'skaya, 1954)

Animals	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Barnacles. . .	111	4394	2044	6822	121,888	10,333	50,889	37,778	224,155	6466	8878	733
Mytilids . . .	0	0	359	2133	78,889	2,087	0	1,289	7,133	0	67	0
Bryozoans . .	0	0	0	1821	3,055	70*	35*	3,111	623	55*	1378	45
Botryllids . .	0	0	0	2910	55*	2,822	2,045	0	89	134	556	0
Oysters. . . .	0	0	0	0	0	55	689	7,778	222	0	0	0
Worms building tubes	0	0	0	0	0	1,744	0	111	0	0	0	0

* Percentage of area covered by fouling.

Table 3

The Settlement of Foulers in Gelendzhiskaya bukhta (the Mean Number of Larva Occupying 1 m^2 in 1954, 1955, 1956, 1960 and 1961) (according to data by Nikitin and Turpayeva, 1958, and Petukhova, in this collection of papers)

Organisms	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Balanus. . . .	0	0	50	0	0	230	26,220	8060	290	3000	0	0
Mytilidae. . .	0	0	150	70	0	130	13,000	4900	750	600	450	150
Lepralia . . .	150	0	0	1130	4900	18,400	13,000	8400	4200	830	300	150
Membranipora .	0	0	50	50	50	200	150	50	0	0	0	0
Bowerbankia. .	0	0	0	0	0	200	1,200	100	0	0	0	0
Botryllus. . .	0	0	0	50	200	280	220	340	100	50	0	0
Hydroidea. . .	0	0	3000	3200	4500	2,500	600	0	0	0	0	0
Spongia. . . .	0	0	0	0	0	200	0	50	0	0	0	0

The study by T. A. Petukhova (in this collection of papers) presents data on the settlement by foulers in Novorossiyskaya bukhta, in which the species composition of larvae of foulers occupying test panels almost does not differ from that of larvae in Gelendzhik.

Table 4

The Settlement by Foulers in Novorossiyskaya bukhta (the mean quantity of larvae occupying 1 m^2 in a decade from 1960 to 1961) (according to data by Petukhova, in this collection of papers)

Organisms	Months			
	VI	VII	VIII	IX
Balanus	28,600	46,260	900	880
Mytilidae	310	51,000	29,880	4,940
Lepralia.	70	190	820	0
Membranipora.	6,000	2,160	1,640	4,820
Botryllus	1,140	9,680	12,040	6,170
Hydroidea	370	0	2,270	18,730
Polychaeta sed.	0	190	5,510	1,020

As seen from Table 4, the main forms in this area were barnacles and mytilids. Here, in comparison with Gelendzhikskaya bukhta, the quantity of gold-stars and membranipores was greater, while the quantity of lepralians was considerably smaller. The total intensity of occupation by larvae was considerably higher than in Gelendzhikskaya bukhta. Thus, during the four summer months (June-September) of 1960, 90,000 larvae occupied 1m^2 of a panel in Gelendzhikskaya bukhta, and 310,000 larvae in Novorossiyskaya bukhta. An especially great influence on the intensity of settlement by the larvae of fouling organisms in the Gelendzhik and Novorossiysk areas is excerised by the wind and temperature. The northeasterly winds can delay, or completely interrupt the settlement by larvae if they persist.

Despite the abundance and a wide distribution of foulers in the Black Sea, the fouling in technical water conduits may be practically absent on the basis of a number of reasons. Thus, when I was investigating the water pipes at four various points in the Black Sea, the mass settlements were observed only at two of the points. In one case, the absence of fouling was explained by the fact that only in the summer months did the sea water flow into the water pipes in addition to the fresh water. Naturally, a considerable dilution of sea water precluded the possibility of settlement and the development of larvae of marine foulers. In another case, the fouling in the water pipes was insignificant because of a peculiar closed structure of water intakes (Kudryavtsev, 1946; Leshchev, 1963).

The hydrobiological investigation of the given water intake of water conduits, which was carried out in 1961, demonstrated that Chthamalus stellatus, Balanus improvisus, and Mytilaster lineatus develop in very small amounts within the water pipes, while a mass fouling consisting mainly of mytilids and small amounts of mytilaceans and barnacles was observed in the adjacent areas. The causes for such a weak development of fouling in the given water conduits will be discussed later (see page 120). Of considerable interest is the finding of Chthamalus stellatus in a closed water conduit, where they live in complete darkness. According to data by N. I. Tarasov and G. B. Zevina (1957), this species is extremely "solariphilic".

In other water conduits, in which the water intake system is open, the main foulers with respect to numbers and biomass were Mytilus galloprovincialis, Mytilaster lineatus, Balanus improvisus, B. eburneus. The other species were of secondary significance, as for instance Cordylophora caspia, Bougainvillia ramosa, Gonothyrea boveni, Actinia equina, Merciereila enigmatica, Ascidiella dispersa, Botryllus schlosseri, and bryozoans.

FOULING IN WATER CONDUITS IN THE SEA OF AZOV

In contrast to the other southern seas of ours, the fouling in the Sea of Azov in general, and on hydrotechnical structures in particular (except for vessels), has remained little investigated up to the present time. The data collected by E. M. Lebedev (1961) concerning the marine fouling on vessels navigating in the Sea of Azov, in connection with their specific utilization, only partly reflects the nature of fouling in this water basin. In order to characterize the fouling in the Sea of Azov, the most complete material can be gained by observations on stationary objects (first of all, hydrographic enclosures) located in the most diverse spots.

The study of marine fouling in the Sea of Azov can lend important data also for the reason that the salinity of the western part of the sea is 17.5°/oo, that of the central part is 10-11°/oo, and that of the eastern part is only 1-2°/oo. In addition, there are ultrahaline areas. Such differences in the salinity of the various areas are responsible for the presence of brackish and euryhaline forms of foulers in the Sea of Azov. Sharp temperature variations during the year (from 0.2 to 31.7°) determine the presence of eurythermal forms in the Sea of Azov, while the shoal water precludes the presence of abyssal forms.

In 1960-1961 I worked together with associates of the Laboratory of Oceanology of the Academy of Sciences of the USSR - namely, with E. P. Turpayeva, Yu. E. Permitin, and R. S. Simkina. We succeeded in carrying out investigations of technical water conduits located in three areas of the Sea of Azov having different salinities - namely, in the areas of Kerch', Zhdanov, and Taganrog. The technical water conduits located in the Zhdanov area - namely, in the western sector of Taganrogskiy zaliv - where the salinity varies from 8 to 9°/$_{oo}$ were subjected to the most thorough and comprehensive investigation. The investigation of the water conduits made it possible to find not only the species composition of marine fouling, but to trace also the variations in the numbers and biomass of the main forms throughout the length of the water supply system — beginning from water intake structures to the final establishments for the cooling of water. As a result new foulers were found in the Sea of Azov, namely: Perigonimus megas and Stiliger bellulus. In experimental conditions we succeeded in elucidating the influence of sea water having different salinities on the foulers (Simkina and Turpayeva, the papers appear in this collection).

In addition, the dynamics of settlement by mass forms of foulers was, /107 for the first time, investigated in the Sea of Azov (Starostin and Turpayeva, the papers appear in this collection).

Among the foulers occupying technical water conduits we found the following sedentary forms: Perigonimus megas, Mercierella enigmatica, Electra crustulenta, Conopeum reticulum, Bowerbankia imbricata, Mytilaster lineatus, and Balanus improvisus. Among active motile forms we identified Stiliger bellulus, Rhithropanopeus harrisii tridentatus, Nereis succinea, and Cardium edule. P. megas and B. improvisus constituted the main forms in marine fouling.

P. megas settlements were found allover the water supply system. At places they formed a continual cover, the thickness of which fluctuated from 1 to 12 cm, whereby in certain spots the length of stolons reached 20 cm. The biomass of hydroid polyps varied from 0.2 to 10.3 kg/m^2 at various places in the water pipes. The greatest mass of hydroid polyps (16 kg/m^2) was observed on screens; a large quantity of mud particles was, as a rule, observed among the dense polyp settlements. Thus, in a sample taken on 20 June 1961, the quantity of mud reached 12 kg/m^2, but the biomass of hydroids amounted to 16 kg/m^2. A pelophilic biocoenosis consisting of round and polychaete worms is formed in the thick mud layer.

B. improvisus forms single and multilayer colonies on the walls of water pipes, their numbers fluctuating from several tens to 30,000 ind/m^2 and the biomass fluctuating from 0.6 to 5.8 kg/m^2.

The number of crabs among the hydroid polyps reached 1500 ind/m^2, their biomass varying from 0.1 to 0.5 kg/m^2 in various places of the water pipes; but on the concrete walls of the water intakes the biomass reached 2 kg/m^2. The number of Nereis succinea equalled 160 ind/m^2 in 1961, the biomass being 0.04 kg/m^2.

The mean total biomass of marine fouling in various places of the water supply system equalled 5.2 kg/m^2, the minimum being 2.97 kg/m^2 and the maximum 12.75 kg/m^2.

Table 5

Variation of Biomass in Marine Fouling on Water Pipes in 1961 (kg/m^2)

Animals	March	End of May	End of July to beginning of August	End of August to beginning of September
Hydroids.	2.70	4.00	4.70	3.47
Barnacles	1.87	2.96	6.83	0.95
Crabs	0.09	0.09	0.06	0.14
Worms	0.09	0.10	0.30	0.02
Mollusks.	0.03	0.20	0.21	—
Totals . . .	4.69*	7.35	12.10	4.58

*(sic!)

It is seen from Table 5 that the greatest magnitude of biomass is reached by the end of the summer season. In September, when the temperature of the water is 9°C, the cessation of growth of hydroid polyps and barnacles is usually observed.

In water pipes that are in constant use one can observe partial separation of fouling from objects and washing off of animals, which are carried by the water stream to the filters of cooling systems, where the other animals (shrimps, young fishes) that pass through the pipes are added to the former.

Table 6

The Mean Weakly Numbers (ind/m^2) and Biomass (kg/m^2) of "Deposit" on Filters in August 1961

Animals	Numbers	Biomass
Hydroids.	—	1.44
Hydroids with bryozoans	—	0.87
Bryozoans	—	0.02
Barnacles	580	0.20
Crabs	1900	0.76
Worms	200	0.01
Bivalve mollusks.	120	0.03
Shrimps	190	0.02
Young fishes.	2855	0.22
Totals	—	4.59 *

*(sic!)

It is seen from Table 6 that a considerable portion of the "deposit" is made up of motile animals, mainly crabs and young fishes. The participation of sedentary animals in the formation of sediments depends on the degree of attachment to the given object and on the velocity of water movement. The barnacles being more strongly attached to the objects are found in considerably smaller amounts than hydroid polyps in the sediments on filters. Observations demonstrate that a continuous calcareous layer, consisting of barnacles in constantly operating water pipes, can resist for years the rather strong hydrodynamic action.

The mass appearance of hydroid polyps in the deposits is observed in the autumn period when the growth ceases and a gradual dying sets in, as a result of which the biomass of fouling decreases considerably toward the spring.

In summer the deposits on filters consist rather frequently only of crabs and fragments of their carapaces, shed in the process of molting.

In 1960 the percentage of weight of the main forms of marine fouling in deposits was as follows:

Animals	Fouling (water pipes)	Deposits (filters)
Hydroids	67	65
Barnacles.	31	3
Crabs.	2	32

A mass appearance of fishes (young and mature) on filters and screens occurs in spring, especially during the period of strong onshore winds. Altogether, 24 species of fishes, including 12 commercial species, /109
have been recorded in the deposits on the screens. In 1960-1961, fishes constituted 6 to 14°/₀ of the total biomass of deposits.

In summer, onshore winds bring a huge quantity of medusae in the area of the water supply system; the biomass of the forms reached 3 kg/m^2 on screens, which calculated for the entire area of the intake screens amounts to hundreds of kilograms. In some days the thickness of the layer formed by fibers of medusae on the intake screens for the water supply system reached 1 cm, which diminished greatly the permeability of the fencing.

During 1960 and 1961, the settlement and development of larval organisms in marine fouling did not occur at a uniform rate (Starostin and Turpayeva, in this collection of papers). In 1960 the settlement of larva of <u>Conopium reticulum</u> and <u>Bowerbankia imbricata</u> occurred by the end of July and the beginning of August. The number of young colonies of the first species reached 60, but of the second species the number reached several thousands per 1 dm^2. The settlement by <u>Perigonimus megas</u> was continuous throughout July, August, and the first half of September. The <u>B. improvisus</u> began to form settlements in the second ten-day period of August; the process continued through the first ten-day period of September, when the number of young reached 260 ind/ dm^2.

Table 7

Calendar Dates of Settlement by the Main Forms of Foulers*

Animals	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1960												
P. megas. . .							3.2	1.7	0.9	—	—	—
B. improvisus							—	14,600	5,900	—	—	—
C. reticulum.							—	180,000	—	—	—	—
B. imbricata.							—	50,000	—	—	—	—
1961												
P. megas. . .	—	—	—	—	15	55	—	160	—	—	—	—
B. improvisus	—	—	—	—	100	1,800	100	91,000	4,000	—	—	—
C. reticulum.	—	—	—	—	—	—	200	2,500	4,000	—	—	—
B. imbricata.	—	—	—	—	—	15,000	810,000	—	—	—	—	—

*Hydroids — in g/m^2, others — ind/m^2. The observations were launched in July 1960.

In 1961 the settlement by the above-mentioned forms was somewhat different - namely: it occurred in two periods, the spring and the summer-autumn periods (Table 7). The hydroids formed settlements in the last ten-day period of May and the first ten-day period of June; then the process ceased until the second and third ten-day periods of August. The mean weight of young P. megas that had established settlements in the spring reached 0.5 $g/\partial m^2$, but in August the weight was 1.35 $g/\partial m^2$. The first settlements of barnacles were observed only in the first ten-day period of June. The second settlement (summer-autumn) began in the second ten-day period of August and continued until the second ten-day period of September, inclusively. The settlement formation by barnacles in 1961 was more intense than in 1960. If in 1960 an average of 80 larvae occupied 1 ∂m^2, in 1961 the number reached about 900. The settlement by B. imbricata began in the first ten-day period of July with the total number of 3 to 5 thousand/∂m^2; but by C. reticulum, the occupation started in the last ten-day period of August and the beginning of September (to 80 colonies per 1 ∂m^2).

A comparison between the resultant data on the occupation by foulers and the data on water temperature in the Zhdanov area shows that the settlement of larvae in the area occurs at temperatures above 15° C.

If a brief (to one month) submergence of panels enables us to find the temperature limits and the season of settlement by larvae, a longer submergence of panels enables us to find the final result of development of fouling in a year or a season, and to arrive at data useful for comparing various periods. If observations are extended in conditions with a pronounced seasonal character, the development of marine fouling and the increase in its biomass depend not only on the temperature (main factor) but also on a number of other associated abiotic and biotic conditions. Systematic observations on the development of fouling on panels that have been in water 1, 3, 6, and 12 months demonstrated that the main biomass of fouling is formed by barnacles and hydroid polyps.

Thus, on the panels that had been in water for a year (the summer of 1960 and the winter of 1960/61), the barnacles constituted 80% of the entire biomass of marine fouling (8 kg/m^2), but the hydroids made up 20%; on the panels that had been in water during the winter of 1960/61 and the summer of 1961, 65% of the entire biomass (1.72 kg/m^2) was made up by hydroids and 35% by barnacles. The total biomass was also dissimilar on panels that had been in water for six months. The smallest biomass was on panels that had been submerged in the fall of 1960 and were taken out in the spring of 1961; the greatest biomass (2.7 kg/m^2) was found on panels that had been in the water during the summer period. The main biomass was formed by barnacles on panels that had been in water for three summer months; the biomass reached 4 kg/m^2 and consisted of 80-95% of hydroids. The development of fouling on monthly panels submerged for the summer period reached 0.3 kg/m^2, whereby its greatest part was formed by B. bankia.

However, when utilizing the listed data, one must account for the fact that the observations on the development of fouling on experimental panels can have only a relative significance in forecasting the magnitude of biomass in technical water conduits, because other factors are applicable in this case; first of all, a permanent factor - the water current. The connection between the magnitude of fouling biomass and the current velocity is seen from the following data on variations in the fouling biomass in various sections of water pipes, which depend on the current velocity:

Velocity of water current, m/sec. . .	0.66	0.8-1.2	1.3	2.4
Biomass, kg/m^2.	2.85	2.1	2.97-3.28	8.66

Many attempts have been made to determine the velocity of water flow that limits the settlement and growth of larvae of animal foulers. The American investigators (Marine Fouling and Its Prevention, 1957*) cite a greater current velocity at which settlement and the growth of the three groups of foulers — the cirripedians, bryozoans, and hydroid polyps — may take place. In experimental conditions, the larvae of B. improvisus occupied the walls of glass tubes at current speeds ranging from 1.15 to 2 m/sec, but at greater speeds young individuals about 16 days old were not able to resist the mechanical impact and were torn off the surface. The greatest speeds at which the barnacles were able to grow flucutated from 0.5 to 1.35 m/sec. The greatest speeds at which the normal growth of bryozoans and hydroid polyps was possible fluctuated from 0.35 to 1.00 m/sec for the former, and from 0.65 to 1.5 m/sec for the latter. The listed values do not agree with the experimental data of the American investigators. It is possible that a correction for the roughness of the surface of water pipes has to be introduced here.

The data obtained by me agree well with the generally recognized fact that the development of fouling - if all the other conditions are equal - occurs more intensely at a more rapid current. As is known, this is explained by the fact that at greater speeds per unit time the sedentary or attached organisms receive more food and oxygen. The Americans themselves list examples: according to data by Hutchins and Deevey (Marine Fouling and Its Prevention, 1957), the accretion of mytilids on buoys is directly proportional to the force of tidal currents. /111

One of the factors for mass development of marine fouling on technical water conduits, which lie in the area where the work is carried out, can be considered to be the abundance of food for foulers. Thus, near the water intakes the plankton biomass was 9 g/m^3 in May 1961; the mass decreased to 3 g/m^3 in August. However, even in the latter case several tons of plant and animal plankton passed through the water conduits in a day. The May plankton was almost exclusively represented by small copepods (Calanipeda aquae dulcis), constituting at the time the main food for hydroids and barnacles.

Simultaneously with the investigation of marine fouling in technical water conduits, we carried out hydrobiological investigations at

* Date of translation. English to Russian. (Editor's note).

various closely located points of Taganrogskiy zaliv and in the nearby estuary of Kal'mius.

All of these places are very much polluted at the present time by household and industrial wastes; however, as seen from the fouling in technical water conduits, this does not have a negative effect on animal foulers. But when compared with data of the previous investigators, who were active during the period when the degree of water pollution was lower, it is seen that considerable changes in the species composition of marine foulers have occurred.

N. M. Miloslavskaya (1927) and E. A. Poteryayev (1939), who had investigated the fauna of the estuary of Kal'mius, pointed out only three species of the animal foulers of that period; namely, Cordylophora caspia, Mytilaster lineatus, and Balanus improvisus. A. S. Razumov (1943a, b), who in 1939 investigated marine fouling in technical water conduits, also noted a mass development of C. caspia and B. improvisus. However, C. caspia was not found in the fouling in technical water conduits in the Zhdanov area in 1960-1961, and in the fouling on a sector adjacent to the water intakes. In all probability, Perigonimus megas in the Zhdanov area was assumed to be Cordylophora caspia (Simkina, in this collection of papers), because it is difficult to admit that the species has completely disappeared from the area during the last 20 years [1].

The investigations conducted by the collaborators of the Laboratory of Technical Biology of the Institute of Oceanology of the Academy of Sciences of the USSR relative to the fouling on piers, concrete structures and buoys, located at various points near the water intakes of the gulf, did not disclose the presence of P. megas; small colonies of the species were found only on the walls of the canal through which the sea water flows into the Kal'mius River.

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[1] In the summer of 1961 we found large quantities of Perigonimus megas in technical water conduits in the Kerch' area, and G. B. Zevina found the species in marine fouling on vessels navigating in the Caspian Sea. If the mass development of Perigonimus megas forces out Cordylophora caspia, the question on the disappearance of the species in the Zhdanov area will be solved and the opinion expressed here, concerning the correctness of the previous identifications of Cordylophora caspia by Miloslavskaya, Poteryayev, and Razumov, will be reversed.

According to data by P. G. Simkina (in this collection of papers), P. megas is a typical euryhaline form which can endure a decrease of salinity to 2-1°/oo, while the speed of the development of its hydranths decreases 14 times as disclosed by comparisons with samples used for verification (8°/oo); a salinity exceeding 5°/oo is needed for a normal development of the species population in natural conditions.

Stiliger bellulus also appeared to be a euryhaline form; according to E. P. Turpayeva (in this collection of papers), the species tolerates salinities ranging from 3 to 45°/oo.

If the western part of Taganrogskiy zaliv in the Zhdanov area lies on the boundary of the mezohaline zone of the Sea of Azov, the eastern part in the Taganrog area belongs to the oligohaline zone with respect to its salinity (1-2°/oo) and faunal composition. The representatives of the old Caspian fauna (Cordylophora caspia and Dreissena polymorpha), which were found in the composition of fouling in technical water conduits located in the Taganrog area, are typical of this zone.

On the basis of hydrological and physical-chemical conditions, Kerchenskiy proliv differs considerably from other sections of the Sea of Azov. The salinity in the strait fluctuates between 12 and 17.5°/oo. A constant inflow of Black Sea waters into Kerchenskiy proliv and a relatively high salinity appear to be the determinant factors in the process of formation and development of fouling.

The samples collected from unused wharves in Kerchenskiy port, which project far into the strait, contained 80°/o of mature and young mytilids whose values were covered with E. crustulenta; B. improvisus occurred singly. The species composition of fouling obtained from a sunken barge was somewhat different. First of all, numerous goldenstars and B. improvisus were in the fouling. The latter was covered with a continuous blanket of hydroid polyps, P. megas, the length of their stolons not exceeding 2-3 cm (without lateral branches). The number of mytilids was very small. The quantity of encrusting bryozoans was considerably smaller than that found on wharves. In addition, individual tubules of M. enigmatica were found.

According to data by Lebedev (1961), the marine fouling on vessels that had been staying in Kerchenskiy proliv for a long time consisted of the following species: Mytilus galloprovincialis, Mytilaster lineatus, Balanus improvisus, B. eburneus, Mercierella enigmatica, Conopeum reticulum, Corophium sp. The total weight of animal fouling on a vessel that had been staying in the strait for a long time (Seiner Mchs-8) reached 24.2 kg/m^2.

The overall picture of fouling on stationary and mobile objects in Kerchenskiy proliv is also preserved in fouling in technical water conduits. But the composition of fouling in various sections of water conduits is determined by the peculiarities of the structure and the use of their individual sections.

As an example of fouling on water intakes one can consider the trash racks, which consist of a metal frame and a rough grid, which is periodically cleaned by mechanical means. The fouling on such trash racks (Table 8) consisted mainly of golden-stars (Ascidella, Botryllus) and hydroid polyps (P. megas), which formed thick layers on sections of the frames. In some places we observed accumulations of mytilids (as long as 5 cm, as well as young ones). Spots of encrusting bryozoans and actinians (Actinia equina) were found. Single barnacles were found all over the surface of the trash racks and on large mytilids and ascidians. Individual spots of fouling were also found on the metal grids.

When examining the qualitative samples, it appeared that numerous tiny mytilids, ascidians, actinians, and nudibranchiate mollusks covered the stolons of hydroid polyps. The same composition of fouling was found on the walls of the intake compartment.

The internal surface of the water supply system is usually cleaned twice a year: by the end of April - the beginning of May, and by the end of August - the beginning of September.

Table 8 /113

Composition of Fouling on Trash Racks
(quantitative sample taken on 12 June 1961)

Animals	Numbers ind/m^2	Biomass kg/m^2
Hydroids	-	2.090
Hydroids and bryozoans	-	0.410
Cortical bryozoans	-	0.050
Ascidians	1300	2.620
Actinians	1200	0.022
Mytilids	1000	1.510
Barnacles	100	0.005
Total	-	6.707

During the investigation the internal wall of one of the water conduit systems was covered by a uniform fouling, consisting mainly of *Perigonimus megas*, the length of its stolons being 3-4 cm. Single *B. improvisus*, tiny mytilids, ascidians, and actinians were found on relatively clean and small sections. Also numerous mollusks, crustaceans, and worms were observed among foulers.

Table 9

Composition of Fouling on the Network of Water Conduits
(quantitative sample taken on 12 June 1961)

Animals	Numbers ind/m^2	Biomass kg/m^2
Hydroids.	-	1.610
Hydroids with bryozoans	-	0.002
Actinians	200	0.002
Ascidians	3,700	0.160
Barnacles	100	0.002
Mytilids.	3,700	0.023
Cardium	120,000	0.126
Syndesmia ovata	2,600	0.005
Gastropoda.	10,600	0.020
Nereis.	800	0.005
Pleatelmiates	100	0.002
Nudibranchia.	300	0.001
Amphipoda	2,000	0.002
Total.	-	1.970 (sic!)

When analyzing Table 9, one can see that the fouling was in its initial stage because about 2 1/2 months had passed since the cleaning of the water pipes; further, the mass settlement of larvae had occurred still later but not before the end of April, when the water temperature began to exceed 10° C.

Clogging of the water conduits investigated by us arises not only from animal foulers but also from plants. The point is that the sector of the gulf contiguous to the water intakes is intensely overgrown with *Zostera*, which, during strong storms, appear in huge quantities on the surface, and are brought into the water supply of the canal and clog the trash racks. Especially great clogging is made by Zostera in the fall when the minute rot, formed as a result of decomposition of the plants, not only clogs the trash racks but also penetrates in huge quantities the water supply system, soiling the cooling system.

Table 10

Species Composition of Marine Fouling in Water Conduits in Various Sections of the Sea of Azov and the Salinity Range of the Species

Animals	Kerch' 17.5°/oo	Zhdanov 8–9°/oo	Taganrog 1–2°/oo	Salinity range of species, °/oo
COELENTERATA				
Cordylophora caspia	—	—	+	0—35
Perigonimus megas	+	+	—	1—35
Actinia equina.	+	—	—	12—35
POLYCHAETA				
Mercierella enigmatica. . . .	+	+	—	7—55
BRYOZOA				
Conopeum reticulum.	+	—	—	14—35
Bowerbankia imbricata	+	+	—	2—35
Lepralia pallasiana	+	—	—	12—35
MOLLUSCA				
Mytilus galloprovincialis . .	+	—	—	10—35
Mytilaster lineatus	+	+	—	8—35
Dreissena polymorpha.	—	—	+	1—17
CIRRIPEDIA				
Balanus improvisus.	+	+	—	0.5—60
TUNICATA				
Ascidiella dispersa	+	—	—	—
Botryllus schlosseri.	+	—	—	14—35

As seen from all that has been said in this section, the marine fouling in the Sea of Azov occupies an intermediate status between fouling in the Black and the Caspian Seas, if the species composition is considered. The main nucleus of fouling in the Sea of Azov consists of representatives of the Mediterranean-Atlantic fauna, characterized by a wide range of salinity tolerance (Table 10), which enabled them to become established not only in the Sea of Azov but also enter the Caspian Sea via the Volga-Don Canal. Some of them (Balanus eburneus, for instance) had passed through the Sea of Azov.

MARINE FOULING IN WATER CONDUITS IN THE CASPIAN SEA

Nothing was known about the composition of fouling in technical water conduits in the Caspian Sea prior to the immigration of representatives from the Pontic-Azov Basin.

During the period that preceded the penetration of new immigrants into the Caspian Sea via the Volga-Don Canal, the species composition of fouling was rather poor, the leadership in numbers and biomass belonging to the bivalve mollusk Dreissena polymorpha and the hydroid polyp Cordylophora caspia; all the other foulers occupied a secondary place. Two of the mentioned forms occurred en masse in the northern, less saline, portion of the sea. But with the appearance of new settlers, substantial changes took place in the composition of fouling in the Caspian Sea

The first immigrant into the Caspian Sea was Mytilaster lineatus, which, as is assumed, entered the sea on the hulls of vessels that had been transported by railway during the civil war.

The first findings of mytilids were made in 1928 by V. V. Bogachev in the Apsheronskiy poluostrov area. In the subsequent years, the species was observed in great quantity throughout the southern Caspian sector (Arnol'di, 193?; Brotskaya and Netsengevich, 1941), occupying also technical water conduits; the mytilid fouling assumed such proportions that measures had to be taken to fight them. In 1947 the thickness of mytilid layers in water pipes reached 10 cm. About 40 tons of mytilids were removed by mechanical cleaning of the pipes (Malishevskiy, 1948).

With the opening in 1954 of navigation in the Volga-Don Canal, the immigration of the species from the Pontic-Azov Basin became regular, which is seen from the following table (Table 11).

Table 11

New Settlers in the Caspian Sea After the Opening of the Volga-Don Canal

Animals	Time of observation in the Caspian	Author
Balanus improvisus.	1955	Derzhavin, 1956 Sayenkova, 1956
B. eburneus	1956	Zevina, 1957
Blakfordia virginica.		Logvinenko, 1959
Electra crustulenta	1958	Zevina, 1959
Rhithropanopeus harrisii tridentatus.	1958	Nebol'sina, 1959
Mercierella enigmatica.	1960	Zevina, 1961
Perigonimus megas	1961	Zevina, 1962

Numerous algae have become transplanted into the Caspian Sea; some of them have been so abundant that they have begun to hamper considerably the utilization of technical water conduits, clogging their trash racks.

It is thought that, the settlements of new immigrants in the Caspian Sea will increase during the coming years because of fouling on the Caspian vessels that navigate in winter in the Black and Mediterranean Seas, as well as in the Atlantic Ocean. Besides, a reverse phenomenon may take place, i.e. the export of local Caspian foulers to other water basins beyond the limits of the Pontic-Azov Basin, in addition to the import of new immigrants into the Caspian Sea.

If the introduction of mytilids alone has greatly affected the fouling /116
in the southern half of the Caspian Sea, the subsequent inflow of new settlers is intensifying the changes, affecting the entire sea area still more. All of these variations have been investigated in marine fouling on vessels and hydrotechnical structures by G. B. Zevina (1961, 1962) during 1951-1961, accounting for biological and nonbiological factors.

As a result of these investigations, it was established that the marine fouling in various areas of the Caspian Sea has increased since the opening of the Volga-Don Canal from 1.5 to 15 times. This increase occurred mainly because of mass development of barnacles, the greatest biomass of which was found on buoys that had been in the water for 8 months — namely, 30 kg/m^2; together with other foulers, the total biomass reached 43 kg/m^2.

Prior to the opening of the Volga-Don Canal, the fouling in technical water conduits in the southern half of the sea consisted mainly of mytilids, hydroid polyps, and bryozoans. Thus, in 1951 the water pipes, supplying water from the polluted Bakinskiy zaliv (Bakinskaya bukhta), had been fouled only by bryozoans (Bowerbankia).

In one of the water pipes, carrying water from the open section of the sea, 99°/₀ of the fouling was made up of mytilaceans; in the automatic water pipe their biomass reached 9 kg/m^2, the thickness of fouling being 10 cm; the fouling in the pressure pipes was somewhat smaller.

In 1961 we repeatedly investigated the water pipes. The composition of fouling was different: in addition to mytilaceans, we found large quantities of barnacles (B. improvisus), the mass development of which was observed in the first years of their appearance in the Caspian Sea. However, at the present time, in connection with the pollution caused by chemical wastes in the sector of the sea that adjoins the water intakes, the fouling on water pipes has begun to decrease.

The fouling on the other water pipe, the water intakes of which are also located on the exposed coast of the sea, but in cleaner water, was richer — its biomass on the walls of the clean water compartment equalled 6.6 kg/m^2, 4.8 kg of which consisted of barnacles, and the remainder of hydroids and bryozoans.

The investigation disclosed that the operation of the water supply system was impaired not only by animal fouling but also by algae (Ceramium sp.) which, during the last years, have densely covered all the stony and cliffy shores adjacent to the place of water intakes. Masses of algae are torn off the objects during strong northwesterly storms and brought into the open water supply of the canal; later, the entire plant accumulation clogs the trash racks, as a result of which their permeability decreases sharply, reaching at times the critical point. In addition, small fragments of algae are brought into the water supply system.

Ceramium sp. also represents a group of newcomers which has found good conditions for mass development in the sea. This alga was first noticed in the Caspian Sea in 1952 by M. S. Kireyeva and T. F. Shchapova (1957).

This fact has to be taken into consideration when new water intake structures are planned, especially in areas where the shores are covered with boulders and cliffs.

Inasmuch as the intense pollution in Bakinskiy zaliv appears to be an insurmountable obstacle for the penetration of new settlers, the fouling in technical water conduits in this area has remained unchanged.

A completely different picture of fouling in technical water conduits /117
was observed in Krasnovodskiy zaliv. If in the autumn of 1955 the fouling in technical water conduits had a clearly pronounced monomorphic character (more than 90°/o of the fouling consisted of mytilaceans), in the summer of 1956 barnacles (B. eburneus) entered the picture. In the spring of the same year, when conducting a most thorough investigation of Krasnovodskiy zaliv, we succeeded in finding only one young specimen of barnacle, but by the end of September their number on completely clean new buoys reached 15,000 ind/m². They were also found in large numbers in technical water conduits and in many artificial basins. In the autumn of 1960, B. improvisus appeared on some buoys, but in November Zevina (1961) found here single specimens of polychaetes (Mercierella enigmatica). In exactly one year the species increased to such a degree that the hulls of some of the wooden cutters, including the propellers, were covered with tubes of polychaetes, which formed a continuous calcareous crust reaching a thickness of 12.5 cm and a biomass of about 30 kg/m² (Bogoroditskiy, in this collection of papers). A similar crust was observed on wharves and occasionally on the grids of water intakes.

In addition, single specimens of crabs (Rhithropanopeus harrisii tridentatus) were observed in the summer of 1961 in Krasnovodskiy zaliv; in the autumn the quantity of the species was extremely great (mainly young). Also B. improvisus was observed in technical water conduits. Thus, Balanus eburneus, B. improvisus, Mercierella enigmatica, Electra crustulenta, and Rhithropanopeus harrisii tridentatus had found suitable conditions in Krasnovodskiy zaliv; later, the hydroid polyp Perigonimus megas joined the above-mentioned species.

Owing to its favorable physical-chemical conditions (relatively high salinity, good heating), Krasnovodskiy zaliv can, at present and in the future, be considered as the main center of concentration and development of all new settlers in the Caspian Sea.

But in connection with the development of urban economy, marine transport, and the petroleum processing industry the threat of pollution is real for the gulf. This can be exemplified by the nearby bukhta Saymonova, which served for 17 years as a place for the disposal of industrial waste and, with its typical fauna and flora, has now ceased to be a natural part of the sea area.

Data on marine fouling in technical water conduits in the northern half of the Caspian Sea are, for the time being, absent.

* * *

It is seen from the discussion of marine fouling in technical water conduits that its species composition and biomass are not infrequently determined by local conditions; therefore, in addition to an overall account on fouling in the system of water conduits, it is necessary to organize a number of local, permanent or temporary, observation points in all the seas of the Soviet Union.

Such observation points or posts could give valuable data for broad theoretical generalizations, and for the plotting of an atlas on the ecology of mass forms of marine fouling.

The plotting of such an atlas on marine fouling would enable the planning organizations to simplify and economize the investigational work associated with finding means to fight the phenomenon in the marine water conduits that are now built.

MEANS OF PROTECTING TECHNICAL WATER CONDUITS FROM MARINE FOULING /113

Plans of technical water conduits to be built on the sea coast must incorporate provisions for protection from fouling. Regrettably, this is seldom done. Usually, the protective means are planned only after the development of fouling and of considerable obstructions in the water supply. This causes additional difficulties, because the prevention of fouling is much simpler and less dangerous than eliminating established fouling. The elimination of fouling within the operating water conduits requires great care, because any sharp action may cause the death of foulers and their separation from the walls of pipes. When the flow of water brings them onto the filters of the water supply system, serious consequences may result.

When selecting the protective means, one must take into consideration the hydrobiological peculiarities of a given area and the ecology of mass forms of fouling. Especial attention must be paid to the dynamics of settlement by larvae of foulers. The elucidation of the peculiarities of the process in various seasons of the year enables us to work out the most effective and economical means for the protection of such establishments.

The existing means of fighting marine fouling in technical water conduits are extremely diverse. They have been developed along the lines of mechanical, chemical, thermal, and electrical actions.

The mechanical means are the simplest. They consist of periodic cleaning of water pipes by hand or with the aid of simple devices. The manual method is the most primitive method, which requires much human work and extreme patience of personnel, and is applicable only in water pipes whose diameter is sufficiently great.

In individual cases, special means are utilized for mechanical cleaning.

Thus, the cleaning of a freely operating water conduit (600 m long) was carried out with the aid of a hollow cylindrical steel ragbolt (Malishevskiy, 1948). Thus it was possible to take off the walls of the water pipe a great quantity of bivalve mollusks (Mytilaster lineatus). The hole in the cylinder made it possible to clean the water pipes without interrupting the water supply.

It is also possible that in the future the hydromechanical method, developed by the "Uralenergochermet" (Bryzgalova, 1959), will be applied.

When using this method the cleaning of water pipes is done with the aid of an attached ball of a special structure, securing simultaneously an increased speed of water movement in the clearance space and a vibratory removal of fouling from the walls of pipes.

The general deficiency of mechanical methods in the cleaning of marine water conduits is the limitation of their application, especially in the system of water supply for industrial undertakings, where the method secures only a temporary effect.

The chemical methods are based on the application of toxic substances that destroy the animal foulers.

The toxic substances are applied in the form of solutions or antifouling paints; they are used for the protection of underwater parts of vessels.

The application of antifouling paints for covering the internal surface of water pipes is considered to be economically unsound, because their effect is of short duration and the process of painting is complex. /119

However, some paints, especially the thermoplastic ones, can be successfully applied for protection against fouling on the external intakes of water supply systems (the trash racks, strainers, etc.). Thus, in 1960 a strainer on one of the factories was painted with thermoplastic paint No. 86. The experiences during a year demonstrated that a thermoplastic cover on a strainer prevents entirely the development of marine fouling on it.

If we consider the fact that the effect of thermoplastic paints is preserved for four years, their use is economically justified.

In foreign countries, the protection of water pipes against marine fouling is achieved by chlorine, copper sulfate, and pentachlorophenolate sodium.

When chlorinating the water, the amount of 0.5-1.0 mg/l of residual chlorine protects entirely the water pipes from the development of marine fouling. In the Soviet Union, chlorine was used for the extermination of slime coatings on the pipes of condensers of steam turbines in the amount of 3.6-5.0 mg/l (Bunkin, 1940; Malishevskiy, 1948; Krushel', 1952, 1955; Rasumov, 1953a, b).

The method of chlorinating the sea water is widely used abroad on the ocean coasts. The use of chlorine in our inland seas may be economically inconvenient due to a high degree of absorption of chlorine by the water (to 12 mg/ℓ in Taganrogskiy zaliv, to 18 mg/ℓ in Krasnovodskiy zaliv, and etc.) and a considerable overexpenditure of chlorine. Also the transportation conditions and the storage of reserves of liquid chlorine may present great difficulties.

The use of copper sulfate in the prevention of marine fouling in water conduits of the Soviet Union was suggested by G. E. Krushel' (1952). By experimental investigations Krushel' found that Cu 6-7 mg/ℓ applied intermittently during one hour intervals would deter foulers for two days. However, the use of this method requires great care because it may cause the intensification of corrosion on the internal walls of water pipes as a result of the creation of a dielectric couple.

The application of the pentachlorphenolate sodium for the fighting of marine fouling in water pipes may be very promising. The laboratory tests, conducted in the Soviet Union and abroad (in America and Great Britain), have demonstrated high toxic properties of the compound. Thus, the solution of the pentachlor-phenolate sodium having a concentration of 0.25 mg/ℓ stops the growth of animals (Iskra et al, in this collection of papers). The testing of this solution on hydroids and barnacles demonstrated that its concentration of 1 mg/ℓ kills the animals in three to five days.

When developing measures of fighting the fouling in water conduits, one must also consider the fact that many of the tested compounds have a selective toxic characteristic. In this connection, it is possible that the use of solutions consisting of a mixture of organic and inorganic compounds, as for instance, phosporus-oxide, zinc oxide, and dinitro-orthoeresol oxide of sodium or the derivatives of thiourea and phenyl ethers would be advisable for the above purposes.

The influence on organisms of high temperature, electric current, and ultrasonic sound can also be considered as physical means of protection of technical water conduits.

The extermination of marine fouling in technical water conduits by hot water is, undoubtedly, a very effective and simple method. The lethal /120
temperature for animal organisms of fouling (mollusks, barnacles, and hydroid polyps) does not exceed 50° C. In tests conducted by Wood (1955), mytilids 5 cm long perished in 14 hours at the temperature of 42° C, but smaller specimens - not exceeding 2 cm - perished in 20 hours. In our tests, the mature specimens of Mytilaster lineatus perished en masse at the temperature of 43° C in less than one-half hour; but at the temperature of 50° C they endured only for one minute. The

time during which hydroid polyps, crabs, and barnacles perish in waters of various temperatures is listed in Table 12.

Table 12

The Time During Which Some of the Fouling Organisms Perish When the Water Temperature is Increased (in tests)

Temperature, °C	Animals	Number of test animals	Duration of test, hours	Condition of surviving animals after the test when kept 1 day in water at 20° C
35	Hydroids	1000	12	Main mass perished
35	Crabs	20	5	All perished
40	Hydroids	1000	2	" "
40	Crabs	20	1	" "
40	Barnacles	30	6	" "

The washing of water pipes with hot water is not always applicable, far from it, because of the presence of an additional water pipe a large quantity of hot water and the washing of the water pipe with the reverse current of water are necessary. Not all of the sedentary fouling organisms that are killed by the hot water fall off the walls at the same time. In order to accelerate the process of separation of the animals from the walls of pipes, mainly mollusks, which stick to the walls with the aid of byssal fibers, Lou Kang-hou (1958) proposes the use of a 1°/o solution of bleaching powder (calcium hypochlorite mixture), containing 38.6°/o of active chlorine. This solution, according to observations by the author, dissolves byssal fibers of mytilids in 10 minutes. As a result of such treatment, the mollusks are separated from the walls of pipes and can be readily washed off by water currents.

The preliminary washing of fouled water pipes with hot water must be carried out very carefully and must be followed by a complete cleansing of water pipes. The plan of subsequent washing must be drafted in accordance with calendar dates of settlement by larvae of fouling organisms.

At the present time, we are conducting tests in the application of electric screens with an alternating current of 220-380 volts for protection against marine fouling. The use of such screens is possible only in the case of small quantities of used water. The larvae passing through the electric field perish or are temporarily paralysed.

Investigations are carried out concerning the effect of electrodynamic shock of several tens of thousands of volts on the larvae of fouling organisms. In the fight against the fouling on vessels ultrasonic means (Marconi protector) are used in the Soviet Union and abroad. As to the protection of marine water conduits against fouling, the ultrasonic method has not been applied. Only preliminary tests have been conducted (El'piner, 1948; El'piner and Feygina, 1957). The use of ultrasonic means against marine fouling on water pipes is limited because of large quantities of water involved and great speeds of its movement.

In America, during the last years, the construction of an additional /121
network of water conduits has been considered when building electrical stations, so that one of the water conduits can be switched off during the operation of the electric station. Such an additional water conduit contains water for 7-10 days, during which the foulers are exterminated and their remains are washed away with a reverse water current.

The protection against marine fouling by the structure of a water intake, described by V. Ya. Leshchev (1953) and K. F. Kudryavtsev (1946), is very promising. A perforated steel concrete pipe about 2 m in diameter and 60 m long is laid in a bed made of large pieces of marl. The upper side of the pipe lies about 0.5 m below the water level. Thus, prior to flowing into the pipe, the sea water must pass through a thick drainage system. The authors note that the given water intakes secures the passage of 1 m^3 of water per second.

The mentioned water intake system has operated since 1930. A new supplementary branch of a freely flowing water conduit having a diameter of 2 m was built in 1948, so that the total water supply now reaches 3.5 m^3/sec.

As was already mentioned (page 105), the hydrobiological investigations conducted by us demonstrated the absence of marine fouling inside the water pipes. The cause of such a phenomenon was elucidated by comparing the plankton samples taken prior to and after the passage of sea water through the drainage system. It appeared that almost all the plankton organisms pass through the drainage system, but that their quantity considerably decreases. The plankton biomass in a freely flowing water conduit appeared to be many times smaller than the plankton biomass in the sea. Such a pauperization of plankton during the filtration of water through the drainage system is the cause that determines the absence of fouling within the water pipes, because the mass forms of fouling cannot develop due to lack of food. According to data by Lou Kang-hou (1958), a sand filter 3 cm thick keeps back the larvae of bivalve mollusks and other fouling organisms.

A closed system of water intakes must find the widest application when building marine water conduits on a small scale. Such a system protects water conduits from marine fouling, eliminating entirely the settlement of larvae and young commercial fishes.

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SPECIES COMPOSITION AND QUANTITATIVE DEVELOPMENT OF MACROFOULING IN THE SEA WATER SUPPLY SYSTEM OF A METALLURGICAL FACTORY ON THE SEA OF AZOV

Abstract

Investigations were carried out with regard to the composition and magnitude of fouling in a system of marine water piping of a metallurgical plant on the Sea of Azov. The forms occurring in mass quantities were Hydroidea — Perigonimus megas, Bryozoa — Electra crustulenta, Bowerbankia caudata, Crustacea — Balanus improvisus.
The biomass of fouling averaged about 8 kg/m^2 in the initial parts of the water conduits and 3 kg/m^2 in the end sections.

The finding of methods to be used in the fight against fouling in sea water supply systems requires, first of all, the knowledge of the characteristics of distribution of fouling within the system of sea water conduits, the knowledge of variations in the species composition, and the quantitative distribution of fouling organisms by seasons, as well as the knowledge of dynamics in the settlement and development of larvae of fouling organisms.

In August 1960 and in March-September 1961 we carried out a hydrobiological investigation of the pipes of the sea water supply system of a metallurgical factory located on the shores of the Sea of Azov.

Approximately 300 samples were taken from the sea water conduit system during the investigation. An area 10 x 10 cm in size was marked on the surface of the fouling. The fouling was removed from the area with the aid of a sharp metallic scraper. The fouling was fixed with 4°/o neutralized formalin.

The quantitative samples of fouling were processed the same way as the quantitative samples of benthos.

SPECIES COMPOSITION OF FOULING

F. D. Mordukhay-Boltovskoy (1960) lists 325 forms of freely living invertebrates for the Sea of Azov. V. P. Vorob'yev (1949) notes 33 benthos species. Of them, only eight species were found in fouling on vessels and hydrotechnical structures: Cordylophora caspia, Mercierella enigmatica, Nereis sp., Balanus improvisus, Balanus eburneus, Mytilus galloprovincialis, Mytilaster lineatus, and corophiids (Lebedev, 1961).

In 1939, the collaborators of the Novorossiysk Biological Station, under the leadership of E. A. Poteryayev, investigated the fauna and flora of the area in the Sea of Azov that adjoins the factory. Their samples contained Cordylophora caspia, Balanus improvisus, Mytilaster lineatus, Cardium edule, Nereis sp., Hydrobia ventrosa, and a number of blue-green algae.

In the technical water conduits of the factory, which were lying in the area, we discovered a slightly different composition of macrofouling: hydroid polyps (Perigonimus megas), bryozoans (Bowerbankia sp.) and electrans (Electra crustulenta), polychaetes (Nereis sp.) and mercierellans (Mercierella enigmatica), bivalve mollusks (Mytilaster lineatus), nudibranches (Stiliger bellulus), barnacles (Balanus improvisus), crabs (Rhithropanopeus harrisii tridentatus). Algae do not grow on the water pipes because of the absence of light.

The absence of mercierellans and mytilaceans in the list of Poteryayev /125
can be explained by the fact that the animals in the area live on the boundary of their habitat. The salinity boundary of their distribution runs about 7-8°/oo (Turpayeva, 1961). The salinity of sea water in the area, according to observations by the hydrometeorological station, varies from 7 to 9°/oo. Even with a small decrease of salinity, resulting from heavy rains, both of the forms may disappear from fouling, reappearing again with an increase of salinity. It is possible that the rhithropanopean crab was absent at the time in the Sea of Azov. As is known, it appeared in the Black Sea about 20 to 25 years ago and has intensely propagated since that time, acquiring new territories.

Analogous suppositions can be expressed about the nudibranchiate mollusk Stiliger bellulus, which was for the first time observed in the Sea of Azov as late as in 1960 (Turpayeva, in this collection of papers).

Two suppositions can be expressed about the hydroid polyp Perigonimus megas, which plays a very significant role in marine fouling on technical water conduits: namely, that the species has either appeared in the area recently driving Cordylophora caspia completely out, which inhabited the area before, or its identification has been incorrect (Simkina, in this collection of papers). The latter case is supported by the fact that, during the two years of our investigation, we did not find C. caspia either in water conduits or on screen structures, or during the investigation of the gulf.

The investigation conducted by us demonstrated that the main fouling animals, occupying the sea water pipes of the factory, are hydroids (Perigonimus), bryozoans (Bowerbankia), and barnacles.

Colonies of hydroid polyps were found along almost the entire water supply system, except for the end sections of the conduits. Often the animals form a continuous cover in the water conduits, the thickness of the layer ranging from 1-2 to 8-12 cm. The length of individual stolons of hydroids in some sections reaches 20 cm.

The multiplication of hydroids in the system of sea water conduits is achieved by asexual and sexual reproduction. The settlement by hydroid larvae in the factory area occurs during the entire summer when temperatures are above 15° C. Two peaks of settlements are observed: in April-May and in July-August (Starostin and Turpayeva, in this collection of papers). Asexual reproduction occurs by gemmation and the fastening of separated parts of stolons to objects at temperatures exceeding 10° C.

In natural conditions (in gulfs, on wharves, stones, and submerged objects in the sea, as well as on piers), a mass settlement of hydroids was not observed.

Another mass form in the water conduits of the factory was B. improvisus. In the water conduit networks and in its individual sections, the barnacles form settlements consisting of one or many layers which blanket the internal surface of the water conduits. After the death of barnacles their external calcareous skeletons remain fastened for a long time; the skeletons appear to be an ideal object for hydroids, bryozoans, and other fouling organisms. In various sectors of the water supply system, one can observe settlements of barnacles reaching 30,000 individuals per 1 m^2 of surface. The barnacles grow only during summer when the water temperature is above 10° C. If the water temperature is below 1° C, the growth of barnacles ceases (Turpayeva and Simkina, 1961). The planktonic larvae of barnacles float in water three to four weeks and can, during this time, be transferred by currents over very great distances. We found `arnacle colonies in the most remote sections of the sea water supply system of the factory; namely, at distances of 2-4 km from the water intakes.

There are two periods of settlement by the larvae of barnacles in the Sea of Azov - the spring and summer periods. The relative and absolute intensities of settlement may vary greatly during the periods in various years. If the settlement is intense the number of young barnacles, occupying their areas in 10 days, in the area of water intakes may reach tens of thousands of specimens per 1 m^2 (Starostin and Turpayeva, in this collection of work).

Thus, in the second half of August 1960, the quantity of young barnacles that had occupied their living area on glass plates, reached 30,000 per 1 m^2 in 10 days.

The investigation of the gulf and the buckets of water intakes, which adjoin the intake structure, demonstrated that in natural conditions barnacles appear to be the main fouling animals. Their mass settlements were found on boulders, piers, and various objects submerged in the ›a. These were dense, usually, one-layer colonies of animals (the diameter of the base of one individual was 4-8 mm), the density being about 10,000 individuals per 1 m^2.

In contrast to water pipes, where hydroids and bowerbankian bryozoas form the main fouling mass, the hydroids are not mass inhabitants in the sea. In natural conditions, the fouling is composed mainly of barnacles and its associate the bowerbankian bryozoa. Among the hydroids and bowerbankians, a mass of rhithropanopean crabs inhabit the niches of barnacle settlements. Thus, in the second half of the summer of 1961 more than 1500 young crabs were found on 1 m^2.

Hydroids, bowerbankians, barnacles, and crabs constitute the leading forms that determine the character of fouling in the water supply conduits of the factory. Bowerbankian colonies settle on the stolons of hydroids, covering the latter entirely. In this case it is impossible to separate the animals from each other.

The role of the nudibranchiate mollusk (<u>Stiliger bellulus</u>) is considerable in marine fouling. Its length reaches 5 mm, and the species is reproduced en masse in water pipes on the stolons of hydroids. The animal feeds on the developing buds and new segments of stolons, as well as on mature hydroids.

Mytilaceans, especially Cardium genus, are found in very small numbers in water pipes. Their greatest number (to 900 ind per 1 m^2) was noted in the section of water pipes supplying the room of sample collectors. Cardium was found singly in the fouling. Of course, this mollusk does not propagate in water pipes; it only enters them occasionally.

Nereis was found in the first sections of pipes and in the main centers of large-scale water supply systems. This form appears to be the most typical accompanying animal in fouling consisting of "hydroids + barnacles". These worms live in the lower layer of fouling; namely, in old and empty shells of barnacles, among the bases of stolons of hydroids which are very muddy.

Mercierella and Electra were found in small quantities in water pipes; their main number was limited to initial sections of water supply conduits and in water intake structures.

Several of the most typical organisms, that determine one or the other type of fouling, can be distinguished in the water supply conduits of the factory, although no sharply defined boundaries exist between the types of fouling. Nevertheless, the species composition and quantitative relationship of fouling organisms is such that the following types can be singled out: "hydroids + bryozoans", "hydroids + barnacles", and "barnacles + bryozoans". The same types of fouling were established for hulls of vessels (Rudyakova, 1958). /127

The first type of fouling - "hydroids + bryozoans" - was found mainly in the initial section of water supply conduits. This type of fouling is, of course, determined by the intense muddiness and dirtiness of the water in the area. The second type of fouling - "hydroids + barnacles" - is more typical of the central sections of the conduits and the cooling system. The third type of fouling - "barnacles + bryozoans" - is most frequently found in the end sections of conduits, i.e. about 2-4 km from the water intakes, where the animals find less food and less oxygen.

THE QUANTITATIVE DEVELOPMENT OF FOULING

The intake structures — namely, the trash racks, water fencing compartments and strainers, accumulators and main network conduits having long diameters, the cooling equipment, and the area adjacent to the factory — were investigated.

The trash racks are metal grids, with the aid of which the first "rough" cleaning of the water entering the water conduit system of the factory was carried out.

When examining the lifted trash racks in July and August 1960 and 1961, it appeared that their external and internal sides were covered by a thick layer of fouling, the thickness on the trash racks being about 10-12 cm. The total weight of fouling on the trash racks reached 16 kg/m^2 in certain cases. On the average, the biomass of marine fouling on the trash racks in 1960 was 1.5 times greater than in 1961 (Table 1-2).

Table 1

Biomass (kg/m^2) of Marine Fouling in the Water Conduit System of the Factory in August 1960

Fouling organisms	Trash rack	Strainers		accumulators	Network conduit		the mean biomass
		external side	internal side		initial section	central section (800 m from the sea)	
Hydroids.	5.95	0.61	1.51	5.50	6.37	0.26	3.02
Hydroids with bryozoans	5.025	0.55	2.00	—	4.16	1.1	0.63
Bryozoans	—	—	—	—	—	—	—
Barnacles	1.15	1.45	2.82	2.00	0.84	5.78	1.61
Crabs	0.375	0.14	0.14	0.01	0.10	0.25	0.10
Polychaete worms. . . .	0.25	—	0.09	—	0.02	0.02	0.04
Bivalve mollusks. . . .	—	0.02	0.05	0.03	0.10	0.01	0.02
Total . . .	12.75	2.77	6.61	7.54	11.59	7.42	5.42

The main mass of fouling - about 70% of the total weight - constituted hydroids and bowerbankians; the length of individual stolons of hydroids reached 15-18 cm. The mass of fouling on the external and internal sides of trash racks usually differed a great deal. On the external side the fouling was about 2 — 2.5 times greater than on the internal side.

Table 2

Biomass (kg/m^2) of Fouling in the Sea Water Conduit System of the Factory in May–September 1961

Fouling organisms	Trash racks	Strainers		Water intake compartments of pumping station	Accumulators	End sections of water conduits		Mean biomass
		External side	Internal side			2 km from the sea	4 km from the sea	
Hydroids.	3.75	—	2.36	—	—	—	—	0.87
Hydroids with bryozoans	3.70	2.10	—	4.4	4.14	—	—	2.04
Bryozoans	—	—	—	—	—	1.0	1.35	0.33
Barnacles	0.30	3.11	0.58	2.2	4.03	2.15	1.45	1.96
Crabs	0.50	0.08	0.02	0.02	0.09	0.12	—	0.11
Polychaete worms. . . .	0.11	0.06	—	—	0.12	0.01	0.05	0.05
Bivalve mollusks. . . .	—	—	0.01	—	0.28	—	—	0.04
Total. . . .	8.09	5.34	2.97	6.62	8.66	3.28	2.85	5.40

Under the layer of hydroids and bryozoans, on the grids of trash racks, one could always observe a layer of barnacles. Their biomass on external surfaces of trash racks was five to six times greater than on internal surfaces. In certain cases the weight of barnacles on external surfaces of the trash racks reached 2 kg/m^2.

Crabs and polychaetes were found among the stolons of hydroids and the colonies of bryozoans. Numerous remains of coastal plants were found on the external surface of the trash racks. All the fouling on trash racks was soiled with mud.

The great biomass of fouling on the trash racks was caused by the fact that they initiated the sea water supply system.

The concrete walls of water intake compartments were covered with a layer of fouling, the biomass of which equalled 6.6 kg/m^2 by the end of the summer of 1961. The greater portion of the biomass - about 67°/o - was made up of hydroids and bowerbankians; the smaller portion - about 33°/o - constituted barnacles. Numerous young crabs (the size of the carapaces ranging from 2.0 to 6 mm) were observed among the stolons of hydroids. The biomass of crabs made up 0.3°/o of the total biomass of fouling.

The greatest quantity of fouling was noted in compartments where the water flow was uniform and constant. Here the length of stolons of hydroids reached 15-18 cm and the biomass was 6-10 kg/m^2. In certain sectors, where the water was stagnant, the fouling biomass decreased to 0.5-1 kg/m^2. In such places, barnacles appeared to be the main foulers.

The strainers, like the trash racks, perform the preliminary cleaning of the water flowing into the pipes. The strainers consist of metal pipes having long diameters and perforated surfaces, through which the sea water flows into the water supply system. When examining the strainers we observed a considerable fouling on their external and internal surfaces.

The species and quantitative composition of fouling on strainers varied considerably with depth. In a typical case, a belt with barnacles 20-40 cm wide was observed along the water's edge on the external surface of the pipe. In the belt the barnacles are small, the diameter of their base being 4-6 mm. They fit tightly together. As many as 20,000 barnacles were observed on 1 m^2.

The lower portion of the pipe, flange and perforations of the strainer /129
were also covered by a considerable layer of barnacles. In contrast to the upper belt, here the barnacles were considerably greater, the diameters of their bases being 8-12 mm. They were not closely packed, but at a certain distance from one another. In such settlements the number of barnacles reached 7,000-8,000 ind per 1 m^2 (fig. 1).

On the surface of the strainer we found a large number of hydroids covered by bowerbankians; they occupied spots between the cases of barnacles. Numerous young crabs - as many as 2,200 ind/m^2 - were found among the barnacles and stolons of hydroids; the biomass of the crabs reached 0.14 kg/m^2. A small amount of mytilaceans - about 200 ind/m^2 - were found among the foulers on the strainers.

In a number of cases, the fouling biomass on the internal surface of strainers was considerably higher than on the external surface, because the external parts of strainers, mainly perforations, were periodically cleaned of the fouling.

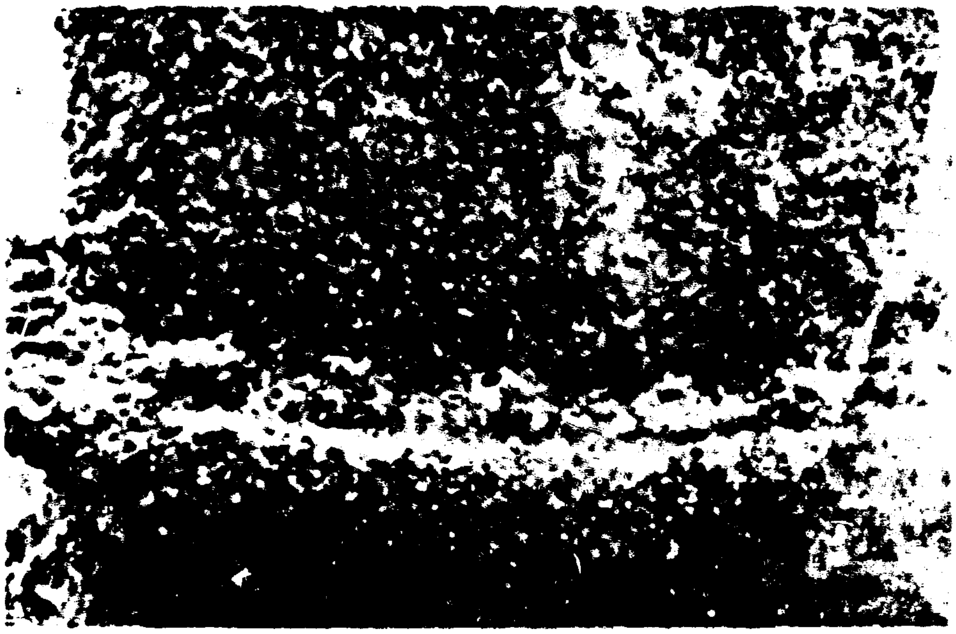

Fig. 1. Fouling on the strainer.

In summer, we observed mature stiligers and their broods on the stolons of hydroids all over the water intake structures.

The accumulators with long diameters are the initial pipes of the sea water supply system for the factory. The investigation of the accumulators demonstrated that a rich fauna of animal fouling develops on the accumulator pipes.

The main foulers on the pipes were hydroids of the Perigonimus genus, bryozoans of bowerbankia sp., and barnacles. The accompanying foulers consisted of nereids, mercierellas, mytilaceans, stiligers, and electra bryozoans.

The internal surface of the accumulator pipes was covered by a multi-annual layer of fouling, consisting mainly of hydroids, barnacles, and bowerbankians. The mean biomass of fouling in the sector remained more or less constant - 7.5-8.5 kg/m^2 - during 1960-1961.

Barnacles, which constitute a considerable part of the total biomass of foulers, form a continual layer on the walls of water conduits. About 80 °/o of the biomass of barnacles were alive, the diameter of the base being 4-8 mm. About 20 °/o of the barnacles were represented by empty shells of large individuals, the diameter at the base of cases being 10-16 mm. Numerous clusters of hydroids, covered by bowerbankians, were attached to the shells of barnacles and among them on the surface of water conduits; the length of hydroid stolons was 8-10 cm.

This fouling consisted of two layers. The lower layer consisted mainly of barnacles, but the upper one consisted of hydroids. A large number of young crabs (the size of the carapaces being 3-11 mm) was found among the stolons of hydroids and empty shells of barnacles. Nereids were found in small numbers, and mytilaceans were observed singly. Mature forms and broods of nudibranchiate mollusks (Stiliger) were found on hydroids. The marine fouling on the accumulator pipes that was observed in 1960 can be assigned to the type "hydroids + barnacles".

In 1961 the character of marine fouling on the accumulator pipes had changed. Bowerbankia sp. had begun to play a substantial role in the fouling. By the end of summer the species had reached such a quantity that bowerbankians formed a continuous layer over hydroids and barnacles. The barnacles, and to a degree also hydroids, were buried under the layer of bryozoans. The biomass of hydroids, overgrown with bryozoans, made up approximately 50 °/o of the total animal biomass. Evidently, the mass development of bryozoans on the fouling type of "hydroids + barnacles", which is typical of the water supply system of the factory, represents the final stage in the development of this community.

The network of water conduits with a diameter of 1200 mm appear to be the basic arteries of the water supply system. These water conduits carry the huge quantity of sea water for the blast-furnace and Martin plants of the factory. Hydroids and bowerbankians develop en masse on the main water conduits of the system, while crabs, polychaete worms, bivalve mollusks, and nudibranches play the secondary role in the fouling.

The investigation of the main network of the water supply system was conducted in August 1960 in two sectors: in the initial and central sectors at a distance of about 800 m from the sea.

The fouling on the initial sector was, on the whole, analogous to that on the accumulator pipes, but the total biomass was 1.5 times greater. The greater portion of the biomass consisted of hydroids and bowerbankians. The stolons of hydroids, stretched along the water flow, form a layer 8-10 cm thick on the surface.

Individual groups of hydroids had the length of 18-20 cm. A layer of barnacles lay beneath the layer of hydroids. The biomass of barnacles made up only 7°/o of the total fouling biomass. A large quantity of crabs - more than 1,500 ind per 1 m^2 (the size of the carapaces being 3-11 mm) was found among the stolons of hydroids in the area. Despite the great number of crabs, their biomass made up less than 1°/o of the total magnitude. A small amount of polychaete worms were observed in small quantities among the clusters of hydroids.

The high value of fouling biomass in the initial section of the water supply system is, probably, determined by the fact that the food and oxygen conditions for animals here are favorable. Besides, it seems that a more intense settlement and growth of larvae, that enter the pipes from the sea, takes place in the initial sections of the water conduits.

When examining the central section of the water supply system, it appeared that the entire internal surface of the water conduits was covered by a continuous layer of marine fouling, which was formed over many years; the thickness of the layer was 5-7 mm. However, in contrast to the initial section of the water conduit, the fouling of the /131
central section contained almost 80°/o of barnacles. The barnacle settlements in this case formed many layers. The shells of barnacles formed 4 to 5 layers. The diameter at the base of the shells reached 14 mm. Only a few barnacles were alive (approximately 20°/o of the total number). The live barnacles were, as a rule, attached to the upper layers of fouling. These were the young barnacles that had settled on the pipes in the fall. The diameter of the base of the live barnacles varied from 4 to 6 mm. Hydroids, which were to a considerable degree overgrown with bowerbankians, were attached to the shells of barnacles. A rather great number of crabs was found among the clusters of hydroids and in depressions between the shells of barnacles. A visual counting showed that five crabs (the size of the carapaces being 16-30 mm) occupied an area of 1 dm^2 by utilising all of its niches. On the average, the biomass in this section was 2.5 times greater than in the initial section, the numerical value being 450 ind/m^2. This number must, however, be considered as somewhat too low, because the crabs are extremely motile and disappear when the samples are taken.

Nereis was found here in small quantities. Of bivalve mollusks, we found mytilaceans in the water conduit. The mollusks were, as a rule, occupying the stolons of hydroids to which the mollusks were attached with their byssuses. The biomass of the mollusks was 10 times smaller than the biomass of the animals occupying the initial sections of the water conduit (see Table 1).

As to its appearance, the fouling of this section belongs to the type "hydroids + barnacles", in which bryozoans and crabs played a substantial part in the overall biomass. A comparison between the biomass of hydroids inhabiting the initial section of the main water conduit and that of hydroids inhabiting the central section of the conduit demonstrates a strong depression of hydroids in this section of the water conduit, which lies at a distance of 800 m from the sea.

In July and August 1961 we examined the water pipes lying at a distance of 2 and 4 km from the sea.

The fouling in both of the sections was approximately the same. The main biomass in both of the cases was made up of barnacles. On the average, 1500-2000 barnacles were found per $1 m^2$; the diameter of their base varied from 6 to 12 mm. A considerable portion of the barnacles were dead. The shells of barnacles and the surface of the water pipes that was free of them were blanketed by a thin continuous layer of bryozoans; approximately an 0.5 to 1.0 cm thick layer was formed by the bryozoan Bowerbankia, which constituted in this case one-half to one-third of the total fouling biomass. Crabs and polychaete worms were observed in the niches of fouling; they made up 1 to 5°/o of the fouling biomass.

Hydroids and bivalve mollusks were entirely absent from the terminal sections of the water conduits. On the basis of the character of fouling it can be assigned to the type "barnacles + bryozoans".

The samples taken from these sections of the water pipes confirm a concept that the fouling biomass decreases in water pipes with an increase in their length.

The cooling system also is subjected to fouling, i.e. the pipe boards of turbine compressors, where a considerable change in the speed of water current and a rise in temperature by 5-9° takes place. The fouling biomass equalled about 1 kg/m^2 here. Within the compartments of the condensers, the distribution of fouling was not uniform. The most intense fouling was observed on the roof of the condensers. It consisted of two layers: a layer of barnacles on the surface and a layer of hydroids on the barnacles.

The fouling on the roofs formed individual spots. In certain places a dense mass of 150-200 barnacles was found, while at other places they were absent. A small amount of crabs was observed among hydroids and barnacles.

A more significant fouling was found in the compartments of the filters of oil coolers. The walls of filter compartments with incoming and outgoing pipes, and the filters themselves, became covered with marine fouling as a result of lengthy utilization without cleaning, the mean biomass equalling 1.75 kg/m^2. The fouling on filters, as on all the other sections of the sea water supply system, consists of hydroids and barnacles. In certain places, the biomass of barnacles reached 3.1 kg/m^2 with a biomass of 12,000 ind/m^2; this was especially true of the internal surface of the filters.

No marine fouling was found in the sewer canal of the factory, which was investigated in various sections as far as the estuary. This is explained by letting the used water, with toxic substances and a large quantity of suspended material, flow into the canal.

As can be seen, almost all of the sea water supply system of the factory is covered by marine fouling. The thickness of the fouling varies, depending on localities, from 1.5 to 12.0 cm.

As seen from Tables 1 and 2, the mean quantity of fouling biomass equalled 5.4 kg/m^2 in 1960 and 1961. The biomass is composed mainly of three animal groups: (1) The hydroid Perigonimus and the bryozoan Bowerbankia, (2) barnacles, and (3) crabs Rhithropanopeus; the two former forms made up about 67% in 1960 and 60% in 1961 of the total fouling biomass; barnacles made up about 30% in 1960 and almost 36% in 1961 of the total fouling biomass. The third group, represented by the crab Rhithropanopeus, made up 1.8% in 1960 and 1.5% in 1961 of the total fouling biomass. Such a steadiness in the average biomass of marine fouling during two years of observations and a relatively insignificant fluctuation in the biomass of the main components of the total biomass attest to the fact that, in this case we have to deal with completely established biocoenoses of fouling which will preserve their typical features with the existing regime of the utilization of the sea water supply system.

The mean biomass of fouling in the conduits of the water supply system of the factory is approximately four times greater than the biomass of fouling on stones and piers in the sea. Considerable differences in species composition and quantity of foulers occupying the water pipes and objects in the adjacent portion of the sea are observed. It was pointed out above that the hydroid biomass in water conduits constituted [illegible]%, but the barnacle biomass made up 31-36% of the total fouling biomass; a mass development of hydroids was not noted on stones and piers in the sea. Here the biomass of fouling is composed mainly of barnacles, which constituted 80-90‰ of the total biomass of fouling, and the bryozoan Bowerbankia and green algae.

It is known that all the foulers feed mainly on small animal organisms (zooplankton), which are caught by them in the surrounding water. In summer the plankton in the factory area consists almost exclusively of copepod crustaceans (Calanipeda aquae dulcis). The biomass of zooplankton (wet weight) equals 9.10 g/m^3 in the period when the growth of hydroids reaches its maximum — namely, during the end of May and the beginning of June 1961. On the average, the biomass of zooplankton for the Sea of Azov is about 3 g/m^3. The very great biomass of plankton in the sea area of the factory is, undoubtedly, a determinant factor for the formation of the huge biomass of fouling in the network of the water supply system.

The quantity of the biomass of fouling is subjected to considerable seasonal variations (Table 3).

The biomass of fouling in the accumulator pipes was rather low in March, equalling only 4.7 kg/m^2. /133

Experiments have demonstrated that the rejuvenation and growth of hydroids and barnacles begins at the temperature of 10°. Such temperature in the area of Taganrogskiy zaliv is usually observed in April. This month marks a gradual increase in the fouling biomass, first by the growth of the surviving individuals of winter fouling, then (from May) by settling and growth of larvae of hydroids and barnacles of the spring generation when the temperature rises above 15° C.

In summer the biomass of fouling gradually increases, reaching the maximum of 12 kg/m^2 by the end of July and the beginning of August.

Observations on settlement of larvae on panels demonstrated that the great biomass of the animals in the sea water supply system is dependent mainly on the spring generation of hydroids, and to a degree on the barnacles. The fall generation of hydroids plays an insignificant role in marine fouling because its greater part is consumed by nudibranchiate mollusks and crabs (Starostin and Turpayeva, in this collection of papers).

Not only does the intense growth and development occur in summer, but also the tearing off of the fouling. The latter process is especially intense in the second half of August and the beginning of September, which is evidently associated with the natural death of fouling in the water pipes.

Table 3

Changes in the Biomass of Fouling (in kg/m^2) in Accumulator Pipes by Seasons in 1961

Fouling Organisms	March	End of May - beg. of June	End of July - beg. of Aug.	End of Aug. - beg. of Sep.
Hydroids.	2.70	4.0	4.70	3.47
Barnacles	1.87	2.96	6.83	0.95
Crabs	0.09	0.09	0.06	0.14
Worms	—	0.10	0.30	0.02
Mollusks.	0.03	0.20	0.21	—
Totals . . .	4.69	7.35	12.10	4.58

By the end of September, the fouling biomass decreases to the amount reached in the spring (March). The data listed in Table 3 can be considered only as approximate values: because the samples were obtained from various water conduits, and different numbers may be obtained if the investigation is more detailed. Nevertheless, the data listed here reflect, undoubtedly, the overall seasonal regularity in the fluctuation of the fouling biomass that exists in the sea water supply system.

THE EFFECT ON MARINE FOULING OF THE VELOCITY OF THE WATER CURRENT IN PIPES

The formation and intense development of fouling in the sea water supply system of the factory occurs at water speeds ranging from 0.8 to 2.4 m/sec, depending on the section of the water pipe. As seen from Table 4, the velocities of water movement did not exceed the limits that would restrict the development of fouling. Moreover, an increase in the velocity of water current within the mentioned limits facilitates the development of marine fouling.

Our observations concerning the development of fouling in sea water conduits of the factory, in connection with the velocity of water movement in the conduits, contradict the data obtained by other authors when conducting tests with the same organisms. The American compilation "Marine Fouling and Its Prevention" (1957*) reports that the maximum velocity of water current that allows a normal growth of barnacles is 2.7 knots, which corresponds to the velocity of 1.1 m/sec, while the maximum velocity allowing the growth of hydroids is 1.5 m/sec. Z. S. Feygina (1954) reports the Dreissena larvae do not settle on objects when the current velocity is 2 m/sec.

Table 4

Changes of the Biomass of Fouling in Water Conduits in Connection with the Velocity of Water Motion in 1961

	Strainers (internal surface)	Accumulator pipes	Water pipe (1.5 km from the sea)	Water pipe (2.5 km from the sea)	Concrete canal
Biomass, kg/m^2	2.97	8.66	3.28	2.85	2.1
Current velocity, m/sec	1.3	2.4	1.3	0.66	0.8—1.2

The differences are possibly determined by various living conditions of animals subjected to tests and found in water pipes: in the pipes we have a group of foulers, but in tests we have individual specimens. The velocities of water movement that restrict the growth of individual specimens of hydroids and barnacles are favorable for the fouler group as a whole. The layer of fouling is not uniform in water pipes. The fouling has numerous depressions, cavities, and convexities. This ruggedness of surface creates turbulences in the water flow along the fouling and it decreases the velocity of current. Thus, conditions for a normal development of fouling are created in water pipes even at relatively great water velocities.

*Year of translation, English to Russian.

BIOLOGICAL SETBACKS IN THE UTILIZATION OF THE SEA WATER SUPPLY CONDUITS OF THE FACTORY

As was pointed out above, the remains of animals inhabiting the sea water supply conduits of the factory and the contiguous sea area cause considerable setbacks in the supply of water as they reach the filters of the blast and Martin furnaces. On filters we can find the same forms that inhabit the water pipes and also medusae (Rhizostoma pulmo), crabs, shrimps (Leander squilla), various fishes and their young, the remains of coastal plants, and pieces of wood — everything that is soaked with water and passes through the trash racks, perforations of the strainers, and the protective grids of pump stations. The quantity and type of the material reaching the grids of pump stations and water cleaning filters vary considerably depending on the season, biological processes in the sea, the force and direction of wind, the quantity and type of fouling in the water pipes, the operation regime of pump stations, and etc.

The greatest quantity of such materials was found by us on the grids of pump stations (Table 5). An especially great quantity of the material was found on the grids of pump stations and on the strainers during onshore winds. A direct relationship exists between the wind force and the quantity of solid material on the grids.

The stronger the wind, the more deposits accumulate. In some days of August 1960-1961, when strong onshore winds were blowing, the quantity of deposits reached 12 kg/m^2/day, but when offshore winds were blowing the quantity decreased to 1 kg/m^2/day. The total weight of animals on the grids of pump stations equalled approximately 7.6-7.8 kg/m^2/day in August 1960-1961. /135

A very substantial role in the formation of deposits on filters of the blast and Martin furnaces is played by the biological processes occurring in the water supply system of the factory; its individual sections, as well as the system as a whole, can be considered as peculiar water basins inhabited by fouling animals. Those animals are detached by the water current from the walls of water conduits during the entire warm season of the year, especially during the second half of the summer when their growth and development reaches its peak; as a consequence, they are brought on the filters of the blast and Martin furnaces. Figure 2 presents a filter of the Martin furnace clogged with deposits and also cleaned of them. The quantity of animals that is brought on

Table 5

Composition of Deposits in the Sea Water Conduits of the Factory in August 1960 *

Organisms	Grids of pump sta.		Filters of blast furn.		Filters of Martin furn.		Mean	
	A	B	A	B	A	B	A	B
Hydroids.	—	1.17	—	2.07	—	1.08	—	1.44
Hydroids with bryozoans.	—	2.04	—	0.50	—	0.09	—	0.87
Bryozoans	—	—	—	0.05	—	0.01	—	0.02
Barnacles	780	0.09	150	0.09	800	0.42	580	0.20
Crabs	4120	0.68	1000	1.35	530	0.29	1900	0.76
Worms	542	0.01	—	—	80	0.01	200	0.01
Bivalve mollusks. . .	—	—	—	0.06	360	0.03	120	0.03
Medusae	—	3.01	—	—	—	—	—	3.01
Shrimps	465	0.06	—	—	110	0.01	190	0.02
Fishes.	2800	0.54	55	0.09	70	0.02	2855	0.22
Totals.	8770	7.61	1205	4.21	1950	1.96	5845	4.59

* A – numbers, ind/m²/day; B – biomass, kg/m²/day.

Table 6

Changes by Months in the Quantity of Deposits on the Grids of Pump Stations in 1961 (kg/m²/day)

Organisms	March	June	August
Hydroids	0.02	0.47	2.18
Barnacles.	—	0.02	0.12
Crabs.	0.07	0.10	1.23
Shrimps.	—	0.04	0.01
Medusae.	—	0.83	3.94
Fishes	0.62	0.60	0.32
Rubbish.	—	0.08	—
Totals	0.71	2.14	7.80

the filters from water conduits is greater than that arriving from the sea. Every change in the operation of the water supply system during the summer unavoidably caused an increase in the quantity of deposits on the filters.

The composition of deposits on the filters was rather uniform in 1961. The deposits consisted mainly of hydroids, which constituted about 61°/o of the total mass of deposits.

Barnacles made up only 5°/o of the total mass of deposits, while crabs and their remains (pincers and carapaces) made up 10°/o, bivalve mollusks 5°/o, and fishes 14°/o.

The quantity of deposits was far from equal in various seasons of the year. As seen from Table 6, the smallest quantity of deposits on the grids of the pump stations was observed in March, when almost 90°/o of the deposits consisted of fishes; the maximum quantity was observed in August, when almost half of the deposits consisted of hydroids, barnacles, and crabs - i.e. of forms inhabiting the internal parts of water conduits; the other half consisted of medusae and fishes - i.e. of the forms that are brought on the filters only from the sea. The quantity of deposits on the filters of blast and Martin furnaces was also subjected to seasonal variations.

Fig. 2. A filter of the Martin furnace.
A - clogged by deposits;
B - after cleaning.

The smallest quantity of deposits on Martin filters (Table 7) was observed in March and June; in March almost 70 °/o of the material consisted of fishes, but in June almost 90 °/o of the material was composed of invertebrates. The maximum quantity of deposits was observed in August; more than 80 °/o of it consisted of hydroids (Fig. 2).

Table 7

Changes by Months in the Quantity of Deposits on the Filters of Martin Furnaces in 1961 (kg/m^2/day)

Organisms	March	End of May - beg. of June	End of July - August	Beg. of September
Hydroids.	0.04	0.18	1.49	0.60
Barnacles	0.03	0.04	0.09	0.07
Crabs	0.09	0.06	0.14	0.10
Bivalve mollusks.	0.04	0.10	0.04	0.02
Fishes.	0.40	0.04	0.07	0.01
Total weight of animals .	0.60	0.42	1.83	0.80
Rubbish	—	0.01	0.01	0.01
Total weight of deposits.	0.60	0.43	1.84	0.81

In August intense dying and detachment of hydroids from the walls of water conduits takes place.

In September, the process of hydroid detachment abates and their quantity on filters decreases, but even then the hydroids form the main mass of deposits on filters.

Twenty-four species of fishes, belonging to 9 families, were observed in the samples taken from the sea water supply system of the factory in 1960-1961.

1. Family Clupeidae

Clupeonella delicatula del. - herring
Caspialosa caspia tanaica - shad

2. Family Engraulidae

Engraulis encrasicholus - anchovy

3. Family Cyprinidae

Rutilus rutilus heckeli - roach
Blicca bjoerkna - white bream
Abramis brama - bream
Abramis ballerus - zope
Gobio gobio - gudgeon
Pelecus cultratus - ziege
Cyprinus carpio - (German) carp

4. Family Mugilidae

Mugil cephalus - striped mullet

5. Family Atherinidae

Atherina mochon pontica - atherine

6. Family Gobiidae

Neogobius melanostomus - melanostome
N. cephalarges - cephalarge
N. syrman - syrman
Pomatoschistrus sp.
Knipowitschia longicaudata - Knipovich robin
Benthophilus stellatus

7. Family Parcidae

Lucioperca lucioperca - pike perch
Percarina demidolfi maeotica - percarina

8. Family Gasterosteidae

Gasterosteus aculeatus - stickleback

9. Family Syngnathidae

Syngnathus typhle - long-winged pipefish
Singnathus nigrolineatus - Black Sea pipefish

It seems that the list is far from complete as regards the actual species composition of the fishes that are brought into the sea water supply system of the factory. The percentage of fishes constituted 6°/o in 1960 and 14.1°/o in 1961 of the entire biomass of animals found on the filters.

Fifteen species of fishes belonging to 7 families were found on the grids of pump stations, on filters of the blast and Martin furnaces, and on perforations of strainers — namely: herring (Clupeonella delicatula delicatula), shad (Caspialosa caspia tanaica), anchovy (Engraulis encrasicholus), roach (Rutilus rutilus heckeli), white bream (Blicca bjoerkna), bream (Abramis brama), zope (Abramis ballerus), ziege (Pelecus cultratus), (German) carp (Cyprinus carpio), striped mullet (Mugil cephalus), atherine (Atherina mochon pontica), melanostome (Neogobius melanostamus), syrman (Neogobius syrman), cephalarge (Neogobius cephalarges), pike perch (Lucioperca lucioperca), etc.

Mainly young commercial fishes are found in the sea water supply system. Thus, the size of pike perch fluctuated from 16 to 25 cm, bream from 15 to 19 cm, carp from 8 to 15 cm, shad from 2.5 to 9 cm, anchovy from 1.5 to 4 cm, sea mullet being about 6 cm, and atherine from 5.5 to 6.5 cm. With respect to age, they represent the last year.

Also mature, sexually mature, and commercial fishes were found in the sea water supply system of the factory. Most often we observed roach (12-20.5 cm) and ziege (28-30 cm); less frequently we observed sea robin (9-12 cm) and syrman (8-12 cm).

The quantity of fishes, found in the water conduits of the factory, and their species composition very from year to year. The greatest number of fishes was observed in the spring, which is explained by migrations associated with spawning and the approach of the majority of commercial fishes to the shore, as well as by the fact that young fishes live at the time in the shore belt.

The use of water in the sea water supply system and the quantity of fish entering the system are interrelated. In March 1961 we observed, on the average, 7240 fish a day on the grid establishments of pump stations. Three thousand of the quantity were commercial fishes, which made up about 0.62 kg/m^2 of fish per day.

In the spring (March-May) we observed the following young and mature fishes on the grids of pump stations, in compartments with unfiltered and filtered water, in the water intakes of pump stations, on filters of the blast and Martin furnaces: herring, shad, anchovy, roach, ziege, carp, bream, pike perch, sea robin, and atherine.

A considerable increase in the quantity of fishes is also observed in the spring on the filters of blast and Martin furnaces. In March 1961 we found 0.117 kg/m^2 of fish per day on the filters of the Martin furnaces, which constituted 66°/o of the total biomass of deposits.

In summer, the quantity of fish that enters the sea water supply system of the factory decreases considerably. In August 1961, the quantity of commercial fishes found on the grids of pump stations was approximately twice smaller than in March.

Only 0.072 kg/m^2 of fish was observed on the filters of the Martin furnaces, which constitutes only about 4°/o of the entire biomass of deposits.

In summer, the species composition of fishes on the grids of pump stations and on the filters changes somewhat. In summer, the representatives of the families of herrings and sea robins prevail in samples. In the second half of summer, the most usual species of fishes found on grids and filters were sea robins and shads; less frequently we observed atherines, small (15-19 cm) breams, white breams, young anchovies, and large (to 30 cm) zieges; roaches were found as single specimens.

Among non-commercial fishes, we found pipefishes and percarinas in the samples. Small Knipovich sea robins (2.5-4 cm) and <u>Pomatoschistus</u> sp. were found in June and July on the grids of pump stations. /139

The transition of fish to the coastal belt in the area covered by the water intakes of pump stations depends, in addition to the spawning migrations, on a number of factors. A very substantial factor is the force and direction of wind. Very many fishes are caught in the sea water supply system of the factory and perish with strong onshore winds.

With strong onshore winds fishes look for a shelter, enter the baffles of the water intakes, and are sucked in by the pumps. Thus, during the third ten-day period of June 1961 with a strong onshore wind, 394 sea robins were found in a catch of one band of the grind of a pump station.

The numbers mentioned above show that the factory plays an important role in the catching of young commercial fishes, thus causing definite losses to the fisheries.

In order to protect fishes from getting into the strainers of the pump station, the bailer of the water intake is protected by a metallic grid having 8 mm meshes. However, the effect of this protective grid was not satisfactory. In a number of places the grid was damaged and it did not cover the bailer to the bottom.

Experiences in hydrographic structures have demonstrated that such protective grids are very effective if kept in good order. They protect fishes from getting into the turbines. The protective grids that are maintained in good working conditions can save a large number of fishes.

CONCLUSIONS

1. The species composition of fouling in the sea water supply system of the factory is extremely poor. Only three species of fouling animals occur en masse in the water conduits: the hydroid polyp (Perigonimus megas), new for the Sea of Azov, the cirripedian crustacean (Balanus improvisus), and the bryozoa (Bowerbankia sp.). Among other accompanying organisms we have the crab (Rhithropanopeus harrisii tridentatus), the polychaeta worm (Nereis sp. and Mercierella enigmatica), the bivalve mollusk (Mytilaster lineatus), and the nudibranchiate mollusk (Stiliger bellulus).

2. The fouling was found in the entire sea water supply system of the factory. However, the species and quantitative relationship among the animals varied with the individual sections of the water system, depending on the distance from the sea, the speed of water current in the pipes, and the amount of dissolved oxygen and food.

3. In contrast to water pipes, where hydroids play the major role among the foulers, the adjacent shallow water area was poorly inhabited by hydroids.

4. A greater quantity of fouling was noted in the initial section of the sea water supply system, i.e. in the accumulator and main pipes having a large diameter. Here the fouling biomass fluctuated from 4 to 12 kg/m^2, the average being about 8 kg/m^2. The most typical groups

of organisms were: "hydroids + bryozoans" and "hydroids + barnacles". In the end section of the water conduits the biomass of animals was small — about 2.8 to 3.2 kg/m^2. The most typical group of fouling was "barnacles + bryozoans". The mean biomass of fouling in the water conduits was 5.4 kg/m^2 in 1960-1961.

5. A rich development of fouling in the water conduits of the factory is determined, first, by a favorable oxygen regime, a commensurate solid base, and a constant supply of great quantities of food by the water current.

6. The stable average quantity of fouling biomass during the two years of observations and the relatively small fluctuations in the relationship between the main components of fouling attest to the fact that in this case we have to deal with a completely established biocoenosis of marine fouling, which will preserve its typical features at the existing regime in the utilization of the sea water supply system.

7. Certain seasonal fluctuations in the biomass of fouling in the water conduits are observed. The greatest biomass (to 12 kg/m^2) was noted by the end of summer. In the fall the biomass decreases by 50-60°/o, as a result of death and separation of the animals from the pipes. The lower layers of fouling remain throughout the year. In the spring, when the temperature rises above 10° C, the development and growth of fouling begins again.

8. Such a speed of water movement, as would limit the development of fouling, was not observed in the water pipes of the factory. Even at the greatest speed of water movement in the pipes (2.5 m/sec), no suppression of fouling organisms was observed in the water pipes.

9. A biological pollution is formed by the detachment of marine foulers as they are brought by the water onto the grids of pump stations and water cleaning filters. The quantity of deposits on filters may reach several kilograms per day by the end of summer, i.e. during the period of intense separation of marine fouling from the walls of the water pipes. In addition, often the deposits are increased by medusae, crabs, shrimps, plants, etc. which are brought into the water supply system from the sea. The minimum value of the deposits is observed in March.

10. Twenty-three (twenty-four according to p. 196/137. Transl.) species of fishes, including 14 species of commercial fishes, were found on the grids of pump stations and on the filters of Martin and blast furnaces. The main mass of fishes, which is brought onto the grids and filters, consists of larvae, small and young fishes. The fishes are brought onto the grids and filters by the current throughout the year, but large masses of them are observed in the spring when the fishes approach the coast.

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I. V. Starostin and E. P. Turpayeva

SETTLEMENT ON WATER INTAKE STRUCTURES OF A METALLURGICAL PLANT BY THE LARVAE OF FOULING ORGANISMS

(Sea of Azov)

Abstract

The fouling on experimental panels exposed in the region of the city of Zhdanov (Sea of Azov) contained Hydroidea - Perigonimus megas, Bryozoa - Bowerbankia caudata, Polychaeta (Sedentaria) - Mercierella enigmatica, and Cirripedia - Balanus improvisus. Larval settlement took place from May to September at a water temperature above 15°.

A mass settlement of hydroids and barnacles was observed in the spring and the autumn, whereas the main mass of bryozoans settled during the summer. The maximum biomass of fouling on the panels reached a yearly value of 80g per 1 dm^2.

The finding of methods to fight marine fouling on hydrotechnical structures is not possible without accurate knowledge of the species composition and quantity of larvae of fouling organisms that establish settlements during the year. In the seas of temperate latitudes, where considerable seasonal fluctuations of temperature are observed, the rate of growth and reproduction of many fouling organisms decreases in winter to a considerable degree or even ceases altogether. In summer, as a rule, several periods of mass settlement by larvae of various fouling organisms are observed, which are associated with changes in water temperature and the natural rhythm of reproduction of each species. The knowledge of initial and final dates of the summer period of settlements, and of the intensity or dynamics of settlement by larvae of individual species of animals helps to determine the most economical regime of processing the water flowing through the pipes.

Foreign publications pay great attention to the problems of dynamics in the settlement and to the succession of the biocoenosis of marine fouling. The investigations conducted during the last period are discussed in a special compilation ("Marine Fouling and Its Prevention", 1957) *. As to the Soviet Union, systematic observations on the process of marine fouling are carried out in Sevastopol'skaya bukhta

* Date of translation, English to Russian. (Editor).

(Severnaya bukhta) (Dolgopol'skaya, 1954) and in Gelendzhik area of the Black Sea (Nikitin and Turpayeva, 1958; Petukhova, in this collection of papers). These studies elucidate the species composition of the Black Sea fouling, the alternation of periods of mass settlement by various forms, differences in the quantitative correlation of fouling forms in various sea areas, and the dependence of intense settlement by larvae on water temperature and onshore winds. The observations demonstrated that the settlement by larvae in the Black Sea occurs during the entire year, but in winter the intensity of the process is usually negligibly small.

The data obtained make it possible to assume that in the northeastern portion of the sea the larval settlement almost ceases during the November-March period (Nikitin and Turpayeva, 1958), but in Sevastopol'skaya bukhta (Severnaya bukhta) the process ceases from January to March (Dolgopol'skaya, 1954).

This study is based on the results of observations conducted for almost two years on the intensity of larval settlement by marine foulers in the Zhdanov area of the Sea of Azov. As we know, such observations had not been carried out in the sea before.

THE METHOD /143

The work was conducted by the method approved for the investigation of dynamics of larval settlement by foulers in Gelendzhikskaya bukhta (Nikitin and Turpayeva, 1958). The frames with pairs of glass panels having a surface of 90 cm^2 were submerged in water at a depth of 0.7 to 1.3 m. The panels were replaced once in 10 days (on the 10th, 20th, and 30th of each month). Some of the panels were kept in water longer — 1, 3, and 6 months, as well as one year. The observations were conducted from April 1960 through September 1961.

The processing of the panels included the counting, measuring, and, if possible, the weighing of single forms (barnacles, polychaete worms, crabs, etc.). The counting of colonial forms (hydroids and some of the bryozoans), which often had formed a thick layer of stolons and lateral branches, was very difficult. The counting of these forms was carried out by three methods. If the development of the organisms was considerable, the foulers were taken off the panels and weighed. If the colonies were very young and had not formed a continuous layer on the glass panels, the quantity of individual colonies was counted, determining the mean length of stolons; then the total length of stolons was calculated. In cases when the stolons of individual colonies had been entangled, forming a continuous layer, the length of all the stolons in certain typical areas 1 cm^2 in size was measured. The results were averaged and reduced to 1 dm^2.

In order to make possible comparisons among the data on the colonial forms, all the data were converted into weight. For this purpose, small segments of stolons of hydroids were weighed on specific analytical balances. The weighing disclosed that 1 mm of a hydroid (Perigonimus megas) stolon weighed 0.01 mg. By using this number as a coefficient, we determined the total weight of hydroids on the surface of glass panels.

RESULTS OF OBSERVATIONS

The intensity of settlement and development of fouling larvae was not uniform during the year. The settlements were formed by larvae in spring, summer, and autumn. The settlements were not formed in the late autumn, winter, and early spring (from October to April).

The results of ten-days of observations show that the settlement by bryozoans and hydroids takes place in the June-September period (Table 1). By the end of July 1960, the greatest amount of settled bryozoan larvae was 60 colonies per 1 dm^2. It was impossible to calculate the quantity of settled bryozoans of the Bowerbankia genus. However, we can note that the development was intense by the end of July and in the first ten-day period of August 1960, when the number of bowerbankians reached several thousands and even tens of thousands per 1 dm^2.

The hydroid larvae formed settlements without interruption during July, August, and the first half of September 1960 (Table 1). Young barnacles appeared on the test panels in the second ten-day period of August 1960. An intense settlement lasted throughout the month — during the second and third ten-day periods of August and during the first ten-day period of September, whereby the number of young settled larvae of barnacles reached in special cases 260 ind/dm^2. The size of barnacles fluctuated very little. More often than not, the greatest diameter at the base was 0.7—1.0 mm, but at times the value even reached 2.5 mm.

Besides, intense settlement was observed by the bryozoan Conopeum reticulum in the second and third ten-day periods of August. In some cases, the number of colonies exceeded 1000 ind per 1 dm^2. All of the surface of ten-day panels was, in addition, always covered by a continuous blanket of pedunculate colonial infusoria, which was mixed with mud.

Table 1

Fouling on Ten-day Panels in 1960.
(the mean data for four pairs of panels, reduced to 1 dm^2)

Length of test	Mean water temp. of ten-day period, °C	*Balanus improvisus*, specimens	Bryozoans: *Conopeum*, colonies	Bryozoans: Bowerbankiana, specimens	*Perigonimus megas*: Length of stolons, mm	*Perigonimus megas*: Hydroids, specimens	*Perigonimus megas*: Weight of fouling, mg	*Mercierella enigmatica*, specimens	Notes
7/21-8/1	27	—	13	350	3200	1250	32.0	—	Many infusoria, much detritus
8/1-8/10	26	—	4	500	650	100	6.5	—	
8/10-8/19	25	62	795	—	920	105	9.0	1	
8/19-9/1	20	84	1000	—	230	1470	2.0	1	
9/1-9/10	[illegible]	54	—	—	257	100	2.5	—	
9/10-9/20	17	5	—	—	217	100	2.0	1	
9/20-9/30	13	—	—	—	—	—	—	—	Small number of infusoria
9/30-10/1	12	—	—	—	—	—	—	—	Very small number of infusoria

The autumn boundary of settlement by foulers was very sharply pronounced in 1960. The settlement of macrofoulers ceased in the second ten-day period of September, and no cases of settlement were observed later on. A comparison of data on the settlement by foulers in 1960 with data on water temperature in the sea demonstrates that the larvae cease to settle when the water temperature drops to 15° C.

In 1961 the beginning of settlement was observed in the second ten-day period of May, when the first single colonies of Perigonimus megas appeared on the panels that had been submerged for 10 days. As seen from Table 2, the water temperature at the time only slightly exceeded 15°. The resultant data enable us to assume that the settlement of larvae of the fouling organisms in the Zhdanov area occurs at a time when the water temperature in the sea exceeds 15°.

The forms of foulers in 1961, as well as in 1960, were barnacles (Balanus improvisus) and hydroids (P. megas). The intensity of their settlement varied greatly during the season (Table 2). Two periods of settlement of the forms were observed — spring and autumn. The spring period of hydroid settlement continues practically for 20 days, i.e. during the last ten-day period of May and the first ten-day period of June. In June, the settlement was very intense: a dense cover of hydroids developed on ten-day panels, the total weight being 500 mg/dm^2. The hydroids did not occupy the panels in the summer period, i.e. from the second half of June to the beginning of August; the occupation was resumed in the second and third ten-day periods of August and was, evidently, more intense than in the spring. The average weight of hydroids on ten-day panels reached 1.35 g/dm^2 in the second ten-day period of August, i.e. it was almost three times as high as the weight of hydroids on the panels submerged in the beginning of June. However, when comparing the data, one must account for the fact that the water temperature in August was almost 5° higher than in June and that, as a result of it, the growth rate of hydroids in August must be higher than in June.

The spring settlements of barnacles in 1961 was very insignificant; /145
the process lasted for approximately 10 days — in the first ten-day period of June when the mean number of young barnacles occupying the test panels was 15 ind/dm^2. Single barnacles settled on some of the panels also in the summer. Only in the second ten-day period of August did the second — autumnal — period of settlement by barnacles begin, which was longer and more intense than the spring period. The autumnal period of settlement by barnacles lasted, as in 1960, more than a month. The maximum intensity of the process was also observed in the third ten-day period of August at approximately the same water temperature as in 1960; but in 1961 the process was ten times more intense than in 1960 (in 1960 about 80 larvae occupied 1 dm^2, in 1961 about 900).

The bryozoans also formed two settlements in 1961. A very intense settlement by bowerbankians was observed in the first ten-day period of July. Their stolons made a rather dense cover on the panels, the

Table 2

Marine Fouling on Ten-day Panels in 1961.
(mean data for two pairs of panels reduced to 1 dm^2)

Length of test	Mean water temp., °C	*Balanus improvisus*, spec.	Bryozoans		Perigonimus megas			*Mercierella enigmatica*, specimens	Notes
			Conopeum, colonies	Bowerbankians, spec.	Length of stolons, mm	Hydranths, specimens	Weight of fouling, mg		
4/20–5/1	12	—	—	—	—	—	—	—	No infusoria, small quantity of detritus
5/1–5/10	17	—	—	—	—	—	—	—	Very few infusoria
5/10–5/20	19	—	—	—	40	—	0.4	—	4 colonies of hydroids, infusoria, detritus
5/20–5/30	21	1	—	—	15,000	1,100	150	—	Barnacles — 0.6–0.7 mm, 140 young colonies of hydroids
5/30–6/10	23	15	—	—	50,000	140,000	500	—	The length of hydroid stolons 10–15 mm
6/10–6/20	24	1	—	150	300	100	5	1	Barnacles — 0.6–0.7 mm, 10 broods of nudibranchiate mollusks
6/20–7/1	2[illegible]	[illegible]	—	—	—	—	—	—	2 crabs with length of carapace 1.5 and 2 mm, 20 broods of nudibranchiate mollusks

Table 2 (con.)

Length of test	Mean water temp., °C	*Balanus improvisus*, spec.	Bryozoans		Perigonimus megas			*Mercierella enigmatica*, specimens	Notes
			Conopeum, colonies	Bowerbankians, spec.	Length of stolons, mm	Hydranths, specimens	Weight of fouling, mg		
7/1-7/10	24	1	—	3000	—	—	—	—	6 broods of nudibranchiate mollusks
7/10-7/20	26	—	—	5000	—	—	—	—	8 broods of nudibranchiate mollusks
7/20-8/1	28	—	2	100	—	—	—	—	20 broods of nudibranchiate mollusks
8/1-8/10	27	2	—	—	—	—	—	—	3 nudibranchiate mollusks, 10 broods of same, 3 crabs with length of carapace 2 mm
8/10-8/20	22	8	—	—	Very many		1350	5	15 broods of nudibranchiate mollusks
8/20-8/30	18	900	25	—	25,000	—	250	—	12 broods of nudibranchiate mollusks
8/30-9/10	—	40	40	—	—	—	—	2	The same

number of specimens equalling 3 to 5 thousands of ind/dm^2. A rather intense settlement formation by Conopeum reticulum (to 80 colonies per 1 dm^2) took place in autumn; namely, during the last ten-day period of August and the beginning of September.

The data of lengthy observations enabled us to form a concept on the role of individual periods of settlement by marine foulers of the given area (Table 3).

The total biomass of fouling on test panels was far from uniform. Also the biomass of individual fouling organisms and their percentages were fluctuating.

The differences in the total biomass on the test panels that had been staying in the water for a year were very considerable. Panel no. 1, which had been in the water during the summer of 1960 and the winter of 1960/61, contained the greatest fouling biomass. Almost 80°/o of the entire biomass on the panel was made up by large barnacles, forming a continuous layer on its surface. Hydroids, which were, more often than not, sticking to the surface of the panels in narrow cracks between the shells of the barnacles, made up only about 20°/o of the total biomass. Panels no. 2 and 3, which had been in the water during the winter of 1960/61 and the summer of 1961, had a smaller biomass than panel no. 1 (4.7 and 9.3 times, respectively). The greater portion of the biomass was made up of hydroids (65-67°/o).

The biomass on the test panels that had been in the water for half a year was also dissimilar. The smallest quantity of fouling biomass was on panel no. 5, submerged in the autumn of 1960 and taken out in the spring of 1961. All of the barnacles observed on the panel had formed their settlements in September 1960, at the end of the settlement period, and they had not matured during the winter. The fouling biomass found on half-yearly panels, which had been in the water during the summer season, was very considerable; but on panel no. 4, which had been in the water in 1960, the biomass was almost three times greater than on panel no. 6, which had been in the water in 1961 (9.5 g/dm^2 or 0.95 kg/m^2). This difference, as in the case of yearly panels, was caused by the greater quantity of barnacles that had formed their settlements in 1960.

The fouling biomass was rather similar on the test panels that had been submerged in the spring for three months in 1960 (panel no. 7) and in 1961 (panel no. 8). On both of the panels the biomass exceeded that of all the half-yearly and even yearly panels no. 2 and 3. This amount of biomass on the mentioned quarterly panels is determined by a very intense development of hydroids which made up 80-95°/o of the total biomass, reaching in both instances almost 40 g/dm^2 (4 kg/m^2). On the

Table 3

Fouling on Panels Submerged for Lengthy Periods (reduced to 1 dm^2)

Period	No. of Panel	Hydroids, g	Barnacles: settled, specimens	Barnacles: live, specimens	Barnacles: mean size, mm	Barnacles: total weight, g	Bryozoans: Bowerbankians, g	Bryozoans: Conopeum, colonies: settled	Bryozoans: Conopeum, colonies: live	Crabs: size, mm	Crabs: number	Crabs: weight, g	Total weight of fouling, g
Yearly Panels													
10.III 1960—28.III 1961 *	1	17,0	—	136	8—14	62,0	—	—	—	6	1	0,02	80,0
20.IX 1960—10.IX 1961	2	11,0	12	5	12—19	4,7	—	35	5	3—6	12	1,5	17,2
20.IX 1960—10.IX 1961	3	5,75	18	4	12—16	2,6	—	28	4	4—6	2	0,25	8,2
Half-Yearly Panels													
10.III—28 VIII 1960	4	2,3	—	120	7—10	22,3	2,4	—	—	—	--	—	27,0
10.IX 1960—10.III 1961	5	—	—	22	0,7—1,0	0,1	—	—	—	—	—	—	0,1
10.III—10.IX 1961	6	6,35	9	5	13—17,0	2,20	1,5	40	5	5,6	6	0,9	9,5
Quarterly Panels													
10.III—20.VII 1960	7	35,0	472	85	3—7	6,40	3,6	—	—	—	—	—	45,0
10.III—10.VI 1961	8	34,8	90	18	3—8	1,5	—	—	—	—	—	—	36,5
10.VI—10.IX 1961	9	--	75	10	10—12	1,8	7,7	164	5	8—10	2	0,3	9,8
Monthly Panels													
1.V—1.VI 1961	10	0,32	1	1	1	—	—	—	—	—	—	—	0,4
1.VI—1VII 1961	11	2,00	—	4	3—4	0,0[illegible]	—	—	—	2—4	15	0,05	2,1
1.VII—1.VIII 1961	12	0,31	—	—	-	—	2,40	—	—	7	4	0,09	2,8

* Young barnacles, singly.

quarterly panel no. 9, which had been submerged from June to September 1961, the weight of fouling mass was several times smaller than on the two preceding panels, whereby almost 80°/o of the fouling on this panel was made up of bowerbankians.

The fouling biomass on panels that had been submerged for just one month in 1961 appeared to be very insignificant. The June panel (no. 11) contained 2.1 g/dm^2 of biomass consisting of hydroids, but the July panel contained about 3 g/dm^2, of which the major portion was made up of bowerbankians.

Not all of the new animals occupying the test panels reach maturity - far from it. The percentage of surviving and growing animals varies, depending on the intensity of settlement and on conditions in the physical and biological environment.

When processing the long-term panels, we succeeded, in some instances, in counting the number of live barnacles and those that had occupied the panels and died; thus we established the total number of barnacles that had formed settlements on the panels. These data make it possible to find the percentage of surviving barnacles in the given area. Most reliable are the data obtained by processing the quarterly panels, because the traces of shells of dead barnacles, evidently, disappear if the testing time is lengthy. Eighteen percent of all the barnacles had survived on the quarterly panel no. 7, 20°/o on the quarterly panel no. 8, and 9-13°/o on the quarterly panel no. 9.

Analogous phenomena were noted also in the case of Conopeum reticulum; 14-12°/o of the colonies had survived on long-term panels no. 2, 3, and 6, and only 3°/o on the quarterly panel no. 9. All this attests to a tight interspecies struggle, which, evidently, takes place during the process of settlement by the foulers.

DISCUSSION OF RESULTS

Differences in the total fouling biomass on various panels result from the process of growth and death of the organisms. When examining the composition of fouling on panels, submerged simultaneously but staying in the water for various periods of time in 1960, a gradual increase in the biomass of barnacles is evident. If the biomass of the young barnacles that had settled in the spring period on the quarterly panel (no. 7) equalled 6.4 g/dm^2, constituting only 14°/o of the total fouling biomass, the biomass of barnacles of the same generation increased 3.4 times constituting almost 90°/o of the total biomass on the half-yearly panel (no. 4); the biomass of barnacles had increased almost ten times on the yearly panel (no. 1), whereby the main portion of the biomass was made up of large individuals of the spring generation of 1960.

Hydroids had been subjected to entirely different variations during the year. It is clearly seen from the panels of 1960 that the greatest number of hydroids were on the quarterly panels submerged in the spring of 1960 (35 g on panel no. 7). The separation of the main mass of hydroids from the panels had occurred in the middle of the summer; their biomass on the panels, that had been exposed to water twice as long, had decreased almost 15 times (panel no. 4). A certain increase in the biomass of hydroids had occurred on yearly panels, possibly, due to the development of the autumnal generation and the regeneration of spring colonies in the autumn and early spring. Analogous variations in the biomass of hydroids were observed on the panels that had been submerged in the water in the spring of 1961.

The same phenomenon of dying and separation of huge masses of hydroids is observed in the given area annually during the second half of the summer (Starostin and Permitin, in this compilation of papers). The causes for the large-scale dying of hydroids are, evidently, a considerable decrease of food in the given area and the development of predators.

We collected plankton samples near the test panels. The collection disclosed that in May the plankton biomass was 9 g/m^3, but in August it was only 3 g/m^3. Not all of the plankton found in August could be used as food for hydroids. Among the plankton organisms we found larvae of crabs and fibers of plant cells, while the entire May plankton consisted of small copepods (Calanipeda aquae dulcis), which can be readily caught by hydroids.

The predators living on the stolons of hydroids - namely, the nudibranchiate mollusks Stiliger bellulus and the crabs Rhithropanopeus harrisii tridentatus - play a significant role in the process of elimination of hydroids. In 1961, the nudibranchiate mollusks (Table 2) appeared in the second half of June. At the beginning their population was rather limited, but by the end of July it reached, evidently, the maximum value, judging by the number of broods on the ten-day panels. S. bellulus feeds on the bodies of hydroids, sucking them out of young sections of stolons in places where the case can be bitten through. We often found large colonies of hydroids which had been so severely gnawed by nudibranchiate mollusks, that neither hydranths nor gonophores were found on their stolons. The crab Rhithropanopeus harrisii tridentatus is found in great numbers among fouling organisms. Also /149 this species feeds on hydroids, gnawing its rather thick stolons and turning the great clusters of stolons into tiny particles of remains. By gnawing through the lower sections of colonies, the crabs evidently intensify the natural separation of hydroids from the objects.

When the data on ten-day observations (Table 2) are compared with those on lengthy observations (Table 3) in 1961, it is obvious that the spring settlements of both hydroids and barnacles play a considerably greater role in the formation of marine fouling than do the autumnal settlements. It is on the basis of the spring generation of hydroids that the great biomass of the species is formed on the test panels and, evidently, on the underwater surface of hydrotechnical structures. On the quarterly panels that had been submerged in the spring of 1960 and 1961, the greatest development of hydroids was observed. The panels, that had been exposed for a year or half a year and the panels that had been submerged by the middle of summer to remain until the autumn (quarter of a year) (panel no. 9, Table 3), contained either a small quantity of hydroids or they were entirely lacking on the panels. It can be assumed that the marine fouling in the tested area is determined mainly by the spring generation of hydroids. The autumnal generation, settling on an occupied surface, is to a considerable degree consumed by predators (mainly by nudibranchiate mollusks and partly by crabs), while the surviving portion cannot form a considerable biomass due to the absence of sufficient nutrients.

Analogous regularity, though less clearly pronounced, is manifest in the formation of settlements by barnacles. The spring generation of 1960 had formed almost the entire fouling biomass of barnacles for the year. The yearly panel taken out of the water in the spring of 1961 contained mainly live and large sexually mature barnacles, which undoubtedly belonged to the spring generation; only the single young barnacles, settled on the shells of the large barnacles, can be regarded as belonging to the autumnal generation. The young barnacles of the autumnal generation, which had occupied the surface that had already been settled, were, in most cases, dead because they had not been able to compete with mature animals.

The role of various generations of fouling organisms in the formation of fouling biomass has not yet been investigated at all. There is no doubt that in the area investigated by us the spring generations of fouling animals have greater possibilities for development than the fall generations. A rich development of plankton in the beginning of summer and a decrease of its quantity during the second half of the summer determine to a considerable degree the intensity of development of animal fouling in a given area. This problem deserves the most careful attention because its study will facilitate the finding of a more economical means of fighting the marine fouling.

CONCLUSION

The marine fouling on test panels in the Zhdanov area (Sea of Azov) consists of hydroid polyps Perigonimus megas, bryozoans Bowerbankia imbricata and Conopeum re''culum, polychaetes Mercierella enigmatica, and cirripedian crustaceans. In addition to these immobile forms, we also found on the panels mobile animals: nudibranchiate mollusks Stiliger bellulus and the crab Rhithropanopeus harrisii tridentatus.

The settlement by fouling organisms was observed from May to September when the water temperature was above 15° C. In winter, when the water temperature was lower, the settlements were not established.

Two periods of mass settlement by larvae of hydroids and barnacles are, as a rule, observed in a year — namely, the spring-summer and the fall periods. The bryozoan larvae form settlements mainly in the middle of summer. The intensity of their settlement is far from being uniform during the maximums. In the last ten-day period of August 1960, the barnacles constituted approximately 80 ind/dm^2 on ten-day panels, while during the same time in 1961 the number was 900 ind/dm^2.

The fouling biomass on test panels exposed for the same periods of time varied, depending upon the season. The yearly panels that had been submerged in the water in the spring of 1960 contained a fouling biomass of 80 g/dm^2, but the panels that had been submerged in the fall of 1960 contained only 9-17 g/dm^2. This difference was caused mainly by the annual variations in the development of barnacles. On the test panels that had been exposed in the summer of 1960 the barnacle biomass reached 62 g/dm^2, but on the test panels that had been exposed in the summer of 1961 the barnacle biomass reached only 5.5 g/dm^2. The greater biomass of barnacles was evidently based on the spring generation. The fall generation, which occupies a settled area, perishes as a rule.

Noticeable annual variations in the total biomass of hydroids were not observed. However, considerable seasonal variations in the biomass of the species were observed. The spring generation of hydroids, which establishes settlements by the end of May and the beginning of June, develops rapidly and reaches a biomass of 35 g/dm^2 by the end of June-July. Later, the greater portion of hydroids are torn off the panels, as a result of which the biomass of hydroids decreases to 6.5 g/dm^2. The fall generation of hydroids does not form dense settlements because, on the one hand, the food supply is insufficient and, on the other hand, the predators (crabs and nudibranchiate mollusks) appear in great numbers.

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T. A. Petukhova

SETTLEMENT BY LARVAE OF FOULING ORGANISMS AND BY MARINE BORERS (TEREDINIDAE) IN THE GELENDZHIK AND NOVOROSSIYSK AREA

Abstract

The dynamics of settlement of the larvae of fouling organisms and marine borers in the region of Gelendzhik and Novorossiysk was investigated during the summer months of 1960 and 1961.

The major forms of marine fouling were Crustacea Cirripedia (B. improvisus), Lamellibranchiata (M. galloprovincialis), Bryozoa (L. pallasiana), and Ascidia (B. schlosseri). The major form of marine borers was Teredo navalis. The intensity of settling was always higher in Novorossiyskaya bukhta, than in Gelendzhikskaya bukhta. Offshore northeastern winds markedly affected the intensity of settling.

A substantial accomplishment in the study of fouling organisms and wood borers is the elucidation of dynamics in the settlement by larvae of the animals. Data on settlement by the fouling organisms for a year in Sevastopol'skaya bukhta (bukhta Severnaya) are listed in a study by M. A. Dolgopol'skaya (1954). Analogous observations were carried out in Gelendzhikskaya bukhta during 1954-1956 by V. N. Nikitin and E. P. Turpayeva (1958). In the same area we conducted observations on settlements by the larvae of marine borers (Ryabchikov and Nikolayeva, in this compilation of papers).

This paper discusses the results of observations on larval settlements of foulers, which were carried out in 1960 and 1961, and on larval settlements of marine borers of the family Teredinidae, which were carried out in 1961.

Special frames, made of stainless steel, and enclosing pairs of glasses were exposed in the sea for observations on settlements of foulers (details of the method are discussed in a paper by Nikitin and Turpayeva, 1958). The frames were suspended on cables between piers in Gelendzhik Port and in the dock of the Novorossiysk ship repair plant. The glasses were replaced in ten days. The removed glasses were fixed, and the fouling on them was subjected to qualitative and quantitative processing. Inasmuch as the settlement by the larvae of foulers almost ceases during winter in the Gelendzhik area (Nikitin and Turpayeva, 1958), my observations were conducted from June to September.

The observation method of settlement by the marine borer is described by P. I. Ryabchikov and G. G. Nikolayeva (see this compilation of papers). Its essentials are as follows. Two small boards 10 x 5 x 2 cm in size were suspended in sea water with the aid of weights at a depth of 1.5 m. The objects were replaced in ten days during June-September 1961.

The composition and quantity of fouling organisms that occupied the test panels in Gelendzhikskaya bukhta and Novorossiyskaya bukhta (Tsemesskaya bukhta) in 1960 varied considerably during the observation period. The main forms inhabiting both of the bays were cirripedian crustaceans — barnacles (mainly Balanus improvisus Darwin), and bivalve mollusks of the family Mytilidae (mainly Mytilus galloprovincialis Lam). The most intense settlement by barnacles in the Gelendzhik area occurred by the end of July and the beginning of August: almost the same intensity of settlement was disclosed by the larvae of mytilids during the same time (Table 1).

Two periods of intense settlement by barnacles were observed in 1960 in Novorossiyskaya (Tsemesskaya) bukhta (Table 3): 1) from the end of June to the beginning of July, and 2) in August.

The mytilids settled in August; the phenomenon was most intense during /154
the first half of the month. In contrast to the settlements in Gelendzhikskaya bukhta, a considerable number of larvae of Botryllus schlosseri settled in Novorossiyskaya (Tsemesskaya) bukhta — namely, 1500 ind per 0.1 m^2 during the first half of August.

The species composition of settlers in 1961 was the same on the test panels as in 1960. However, the duration and intensity of the process varied considerably, as regards the main fouling organisms. In Gelendzhikskaya bukhta (Table 2), the settlement of barnacle larvae gained momentum during one and one-half months (June — first half of August), but the intensity of the process by cypris larvae was 1.85 times lower than in 1960. The settlement by mytilids was also less intense — namely, 2.8 times less than during the same time in 1960.

Table 1

Settlement by Fouling Organisms in Gelendshikskaya bukhta (number of larvae per 0.1 m^2) in 1960

Foulers	1.VI 12.VI	12.VI 21.VI	21.VI 1.VII	1.VII 11.VII	11.VII 21.VII	21.VII 2.VIII	2.VIII 11.VIII	11.VIII 21.VIII	21.VIII 1.IX	6.IX 12.IX	12.IX 21.IX	11.X 21.X	21.X 31.X
Balanus sp	—	—	—	—	51	1881	3229	13	38	—	—	—	—
Mytilidae gen. sp	—	—	—	—	633	2465	215	152	13	—	—	—	—
Gastropoda gen. sp	—	—	—	—	87	51	25	13	25	—	—	13	51
Polychaeta gen. sp	—	—	13	—	13	38	13	25	13	—	—	—	—
Mercierella enigmatica Fauvel	—	—	—	—	—	—	13	—	63	—	—	—	—
Lepralia pallasiana Moll	190	51	405	87	190	351	63	—	—	—	51	51	—
Conopeum reticulum L.	—	—	25	—	51	13	—	13	13	—	—	—	—
Bowerbankia gracilis Jelgy	—	—	—	—	—	—	—	13	—	—	25	—	—
Botryllus schlosseri Sav	—	—	—	—	—	25	13	63	51	13	13	13	—
Hydroidea	—	—	—	—	—	—	—	—	—	—	13	13	25

Table 2

Settlement by Fouling Organisms and Marine Borers in Gelendshikskaya bukhta (number of larvae per 0.1 m^2) in 1961

Foulers	1.VI 12.VI	12.VI 21.VI	21.VI 1.VII	1.VII 11.VII	11.VII 21.VII	21.VII 2.VIII	2.VIII 11.VIII	11.VIII 21.VIII	21.VIII 1.IX	1.IX 11.IX	11.IX 21.IX	21.IX 30.IX
Balanus sp	—	101	—	1744	1213	1468	101	127	—	—	—	—
Mytilidae	51	—	—	—	861	228	25	46	—	—	—	—
Teredinidae	—	5	27	11	93	43	16	305	101	6	21	62
Gastropodae gen. sp	25	—	303	—	—	25	—	—	—	—	—	—
Lepralia pallasiana Moll	127	177	303	25	101	51	—	—	—	—	—	—
Botryllus schlosseri Sav	25	25	—	—	—	25	—	—	25	—	—	—
Hydroidea gen. sp	—	25	25	—	—	—	—	—	—	—	—	—

Table 3

Settlement by Fouling Organisms in Novorossiyskaya (Tsemesskaya) bukhta (number of larvae per 0.1 m^2) in 1960

Foulers	1.VI 12.VI	12.VI 22.VI	22.VI 1.VII	1.VII 12.VII	12.VII 22.VII	22.VII 1.VIII	1.VIII 11.VIII	11.VIII 22.VIII	22.VIII 1.IX	1.IX 12.IX	12.IX 22.IX	22.IX 4.X	4.X 12.X	12.X 20.X
Balanus sp.	354	1190	3850	202	241	5340	4	25	—	63	25	—	25	25
Mytilidae sp.	—	—	38	51	134	9600	2776	684	—	165	—	329	—	—
Gastropoda gen. sp	—	—	—	—	—	38	89	1001	—	13	38	51	—	25
Polychaeta gen sp	—	—	13	—	—	13	13	101	—	—	—	—	101	—
Lepralia pallasiana Moll	633	177	257	13	13	101	63	25	—	139	90	253	—	76
Conopeum reticulum L.	51	127	25	—	266	1543	1241	665	—	114	201	302	430	354
Botryllus schlosseri Sav	—	25	25	—	—	—	152	25	—	519	620	734	253	201

Table 4

Settlement by Fouling Organisms and Marine Borers in Novorossiyskaya (Tsemesskaya) bukhta (number of larvae per 0.1 m^2) in 1961

Foulers	1.VI 12.VI	12.VI 22.VI	22.VI 1.VII	1.VII 12.VII	12.VII 22.VII	22.VII 1.VIII	1.VIII 11.VIII	11.VIII 22.VIII	22.VIII 1.IX
Balanus sp	—	—	329	1165	1620	694	—	51	76
Mytilidae sp.	25	—	—	—	329	75	1290	456	1240
Teredenidae sp	1	1	14	28	212	334	3900	995	196
Gastropoda	—	—	—	—	51	—	25	—	—
Polychaeta	—	—	—	25	—	—	—	—	25
Lepralir pallasiana Moll	—	—	—	25	—	—	—	—	—
Conopeum reticulum L.	51	—	76	76	76	152	127	25	25
Botryllus schlosseri Sav	—	—	25	25	101	—	25	25	51
Hydroidae	25	—	—	—	—	—	51	—	202

Teredos established insignificant settlements in 1961 in Gelendzhikskaya bukhta, the peak of activity being reached during the second half of August. Because the main pest of wooden structures in the Gelendzhik and Novorossiysk area is Teredo navalis (Ryabchikov and Nikolayeva, in this compilation of papers), it can be assumed that in this case the greater portion of larval settlements pertains to this species.

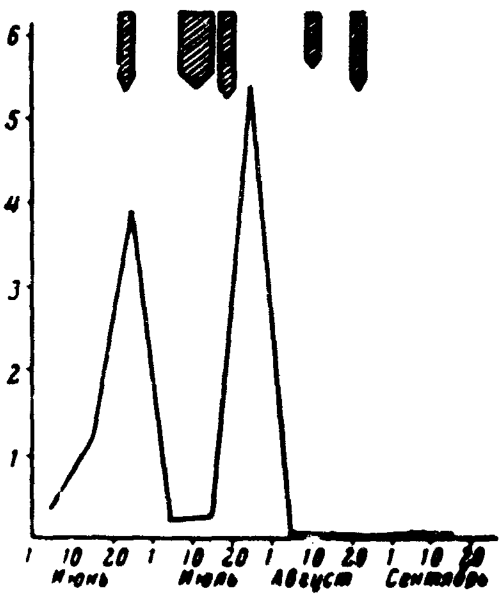

Fig. 1. Intensity curve of settlement by barnacles in Novorossiyskaya (Tsemesskaya) bukhta in 1960. The arrows denote onshore winds (applicable also to fig. 2 and 3).

Key. y-axis: number of larvae in thousands per 0.1 m^2
x-axis: June - July - August - September

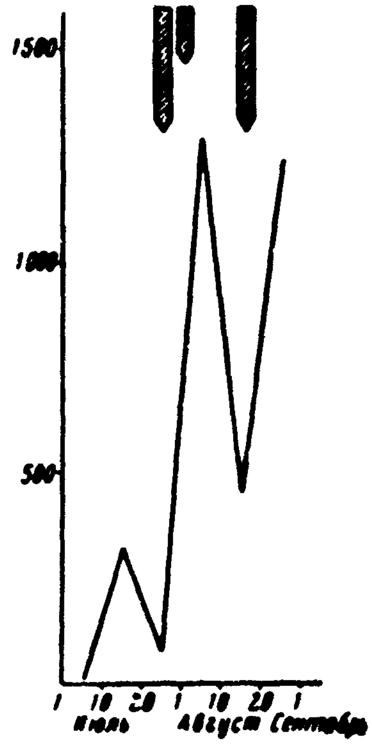

Fig. 2. Intensity curve of settlement by mytilids in Novorossiyskaya (Tsemesskaya) bukhta in 1961.

Key. y-axis: number of mytilids per 0.1 m^2
x-axis: July - August - September

Similarly, in Novorossiyskaya (Tsemesskaya) bukhta (Table 4) the intensity of settlement by marine foulers in 1961 was considerably lower than in 1960. The greatest intensity of settlement by barnacles was observed in July, the number of larvae being 3.3 times smaller than in the preceding year. Also the mytilids formed rather limited settlements at the time.

The teredos formed very considerable settlements in Novorossiyskaya (Tsemesskaya) bukhta in 1961. The maximum of their activity was reached in the second half of August, when about 4000 larvae occupied 0.1 m^2.

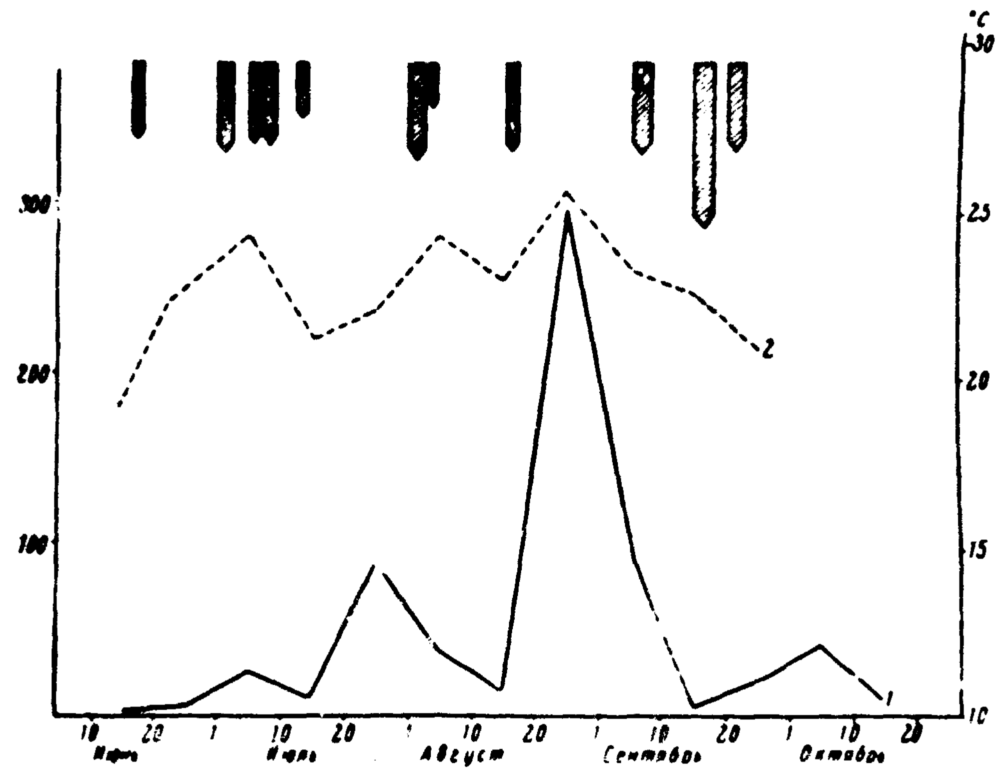

Fig. 3. Intensity curve of settlement by teredos (1) and changes of water temperature (2) in Gelendzhikskaya bukhta in 1961.

Key. x-axis: (left) number of larvae per 0.1 m^2; (right) temperature in °C.

y-axis: June - July - August - September - October.

Examining the character of settlements established by Teredo navalis larvae in Gelendzhikskaya bukhta and Rybatskaya bukhta, P. I. Ryabchikov (1957) notes that a great influence on the settlement of larvae is exercised by northeasterly winds. Driving out the surface water rich in larva into the open sea, the offshore winds cause the upwelling of bottom water in the bays, which is devoid of larvae. Also, Nikitin and Turpayeva (1958) stress the considerable influence of northeasterly winds on the intensity of settlement by larval foulers in Gelendzhikskaya bukhta.

The data obtained by me confirm in general the indicated relationship. Thus, the sharp decrease in the quantity of barnacles that had settled by mid-July 1960 (Fig. 1) in Novorossiyskaya (Tsemesskaya) bukhta was, evidently, caused by offshore winds; similarly, it is possible that the curve with three peaks showing the settlement by mytilids in Novorossiyskaya (Tsemesskaya) bukhta in 1961 was associated with the effect of the northeasterly winds (Fig. 2). The same regularity is traced in the curves showing the larval settlements of teredos in Gelendzhikskaya bukhta in 1961 (Fig. 3). The abrupt decrease in the process of larval settlement by the end of July and the end of August was, undoubtedly, caused by the action of northeasterly winds. Strong offshore winds can delay the beginning of mass settlement by larvae of foulers. Thus, in 1961 the mass settlements of barnacles in Gelendzhikskaya bukhta were originated in the first ten-day period of July, but in 1960, during the third ten-day period of July the process started only after the cessation of the strong winds that lasted from 8 to 18 July.

When studying the fauna of marine borers, Ryabchikov (1957) became convinced that in Novorossiyskaya (Tsemesskaya) bukhta the number of teredos is considerably greater than in Gelendzhikskaya bukhta. The data on the intensity of settlement by teredos in both of the gulfs /156 confirm the above conclusion. In Novorossiyskaya (Tsemesskaya) bukhta 5985 larvae settled on 0.1 m^2 during the entire settlement period of 1961, but in Gelendzhikskaya bukhta the value reached only 690. This regularity is somewhat less pronounced when one examines the total intensity of settlement by the larvae of foulers. Thus, from the beginning of June to the end of August 1960, 30,000 larvae had occupied 0.1 m^2 in Novorossiyskaya bukhta and only 11,000 in Gelendzhikskaya bukhta; during the same period of 1961 the values for Novorossiyskaya (Tsemesskaya) bukhta and Gelendzhikskaya bukhta were about 9,000 and 7,000, respectively.

The causes for the differences have not yet been elucidated. According to Ryabchikov (1957), the differences with respect to marine borers are associated with the configuration of the port and a greater quantity of wood in Novorossiyskaya (Tsemesskaya) bukhta. However, an exhaustive explanation of the phenomenon can be based on many years of observations on settlements by the larvae of marine foulers and borers, and on simultaneous studies of the hydrological and meteorological regime in the area.

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THE BEGINNING OF COLONIZATION OF THE SEA OF AZOV BY SEVERAL SPECIES OF MARINE BORERS OF THE FAMILY TEREDINIDAE

Abstract

The study discusses the propagation of the shipworm which has penetrated the Azov Sea during the last few years, owing to the increased salinity of this basin.

The investigations showed that the Sea of Azov is presently inhabited by two species of shipworm: Teredo navalis and Teredo pedicellata. The former was collected along the southern coast from Cape Kazantip to Temryuk and on the north coast near the settlement of Kirillovka. The second (T. pedicellata) was encountered only near the settlement of Mysovaya (Crimean coast of the Sea of Azov).

INTRODUCTION

Five species of wood borers are found in the Black Sea. Three of them, namely the bivalve mollusks of the family Teredinidae — Teredo navalis L., T. pediceliata Quatref., and T. utriculus Gmelin —, are the most dangerous pests of wood in sea water. If the conditions are favorable for them, they destroy wood with a surprising speed and can, in certain cases, put out of order underwater parts of port structures in a year or even during one warm season. The planking of wooden vessels can sometimes be destroyed by teredos in two to three months. In Soviet and foreign literature, as well as in marine practice, all the species of teredos that inhabit wooden objects are referred to as "ship" or "pier worms".

Two species of wood-boring crustaceans — namely, Limnoria tripunctata Menzies (order Isopoda) and Chelura terebrans Philippi (order Amphipoda) — commit much less harm to wooden structures. In contrast to teredos, limnorians cannot penetrate deep into piers or any other part of the structures. Settling on the surface of wood, they destroy it slowly, layer after layer. Limnorians, which are often found together with teredos, cannot commit a noticeable damage to a wooden structure during the time the latter may put the structure out of use. Limnorians, as a rule, do not damage vessels that are on the move; they occupy the hulls of immobile vessels (for instance those that are moored for a lengthy time period). In this case, limnorians gradually infest the planking, keel, and stern, eating the wood slowly as in the case of stationary structures. As to the chelurans that accompany limnorians, they are unable to damage wooden objects independently and can only slightly widen the burrows made by limnorians.

The mentioned species, with the possible exception of T utriculus, are widely distributed in the Black Sea, reaching great numbers. However, their distribution is characterized by great inequalities; also their numbers fluctuate considerably from year to year. The causes for the variations lie, evidently, in temperature changes and to a smaller degree of salinity.

Although geographically, the Sea of Azov is but a gulf of the Black Sea, the Kerchenskiy proliv, which connects the water basins, divides them hydrobiologically to a considerable degree; at least, to the present time the strait has represented a boundary that has not been /158
traversed by marine borers and also by other Black Sea animals. Only the most widely distributed species of the ship worm T. navalis has been found in the strait and has committed here relatively small damage, as it is sharply decreasing in numbers toward the north, ceasing to exist in the entrance to the Sea of Azov (Ryabchikov, 1957).

Despite a thorough knowledge of the shipworm, it has not been found in the Sea of Azov. The local fishermen do not know anything of the worm, though it is well known to the fishermen along the Black Sea coast. Meanwhile, small wooden vessels and boats have been used in the intense fishing in the Sea of Azov since ancient times, and great numbers of light piers and piles for seines and nets have been in operation in the sea. In such conditions, even a casual and temporary appearance of the shipworm, which rapidly damages wood, could not remain unnoticed. It need be added also that the attempts to find wood borers in the Azov water, by exposing wooden objects selected for special observations, have given negative results. Thus, in 1931, when large-scale investigations of wood borers were conducted in the Black Sea, a test pier and trap (a set of blocks, one of which had to be taken out of the water each month) were exposed at mys Kazantip in the Sea of Azov. No borers were found, and the observations were discontinued (Zhukov, 1934). The same results were obtained by us when exposing traps in 1954.

The stability of the hydrobiological boundary in Kerchenskiy proliv, which has existed for many centuries, was maintained by the low salinity of the Azov water and the general water flow toward the Black Sea. However, one cannot imagine the boundary as mechanically immovable. There is no doubt that the compensatory currents in the bottom layer of water take, from time to time, into the boundary of the Sea of Azov a certain amount of saline Black Sea water, which contains pelagic larvae of the animals during the reproduction of teredos. This process can be repeated many times, but it does not lead to the colonization of the Sea of Azov with the marine borer, as long as the salinity remains below the level that is necessary for the survival and development of the larval stage of teredo. At the present time, this level has been determined experimentally: it appears to be by 1.5°/oo above the mean annual salinity of the Sea of Azov.

In his time N. I. Tarasov (1943) pointed out that the expected increase in the salinity of the Sea of Azov, which is associated with the building of the Volga-Don and Tsimlyansk water reservoir, may entail the appearance of the shipworm in the Azov waters. This was a timely and necessary warning; however, no one knew at the time what stage of teredo development is most sensitive to low salinity; neither the limit of minimum salinity at which a normal life of the organism in this stage is possible was known. By the end of the 40's and the beginning of the 50's the mean salinity of the Sea of Azov increased to the level that permitted the existence of the larvae of T. navalis, which, of course, marked the beginning of colonization of the water basin with teredos. At the present time, two species of marine borers have entered the Sea of Azov — namely, T. navalis and T. pedicellata, but their numbers are limited.

The objective of this study is to elucidate the means of propagation and the rate of local population growth of the animals.

The problem is of great theoretical interest, because it enables us to /159 utilize for scientific purposes a large-scale test associated with the results of hydrotechnical structures on the Don and Kuban' rivers, as well as with changes in climatic conditions. Thus, it is possible to compare the results of observations on the same animals in two neighboring seas that preserve considerable hydrological differences and to verify in natural conditions the results of laboratory tests.

Our tests were conducted during 1958-1961 along the south coast of the Sea of Azov, and, at the beginning of the tests, we observed the structures that had been damaged by teredos, witnessing either live or dead animals.

THE SALINITY REGIME OF THE SEA OF AZOV AND THE REACTION OF BLACK SEA TEREDOS TO LOW SALINITIES

The salinity regime is of great significance among the factors determining the propagation of marine borers in the Sea of Azov. As is known, the borers may damage any wooden object submerged in the sea. In the Sea of Azov, where the quantity of natural wood is insignificant, large quantities of wood are concentrated only in areas with stationary or temporary structures — piers and piles for nets. These structures are found, as a rule, in the coastal belt of the sea and, consequently, only here can mass settlements of marine borers be formed. In order to forecast the distribution of teredos in the Sea of Azov, it is necessary to know its salinity regime in coastal areas.

The salinity regime in the coastal belt west of Taganrogskiy zaliv, as well as west of Kerchenskiy proliv, is characterized by the data of hydrometeorological stations located in the villages of Mysovoye (mys Kazantip), Strelkovoye, and in the towns of Berdyansk and Zhdanov. The data give an idea on the salinity regime in the southern portion of the Sea of Azov west of Kerchenskiy proliv (Mysovoye), in the coastal belt along the west (Strelkovoye) and north (Berdyansk) shores, and in the most saline part of Taganrogskiy zaliv (Zhdanov).

It is rather difficult to characterize the salinity regime of coastal waters in the southern part of the Sea of Azov east of Kerchenskiy proliv and along the east coast. The salinity distribution in the coastal zone of this portion of the Sea of Azov is very complex due to the effect of the Kuban' river and the great number of sea arms (liman) connected with the sea. The Kuban' flows into the Sea of Azov by means of three branches, and its effect is manifest from Peresyp Channel to Achuyev (mys Achuyevskiy), varying from place to place.

The meteorological stations of the area are located in Temryuk where the Kuban' river discharges its waters and at the sea arm in Primorkso -Akhtarsk. The information available at the stations give an idea on the salinity of water in a very limited area. As L. A. Shul'gina (1955) remarks, considerable differences exist with respect to the values of salinity based on observations of the meteorological stations and on observations of expeditions in the sea that were conducted in the same area. Thus, according to data by the Temryuk meteorological station, the mean monthly salinity was once by 5.91°/oo lower than the value obtained by expeditional observations for the same month. The difference reached 6.28°/oo for the Primorsko-Akhtarsk area. Therefore, it is impossible to use the data of the mentioned meteorological stations for the characterization of salinity regime in the coastal belt of the sea.

Neither is it possible to use for the purpose the data of expeditional observations, if the observations have not been conducted in the immediate vicinity of shores, because, according to data by E. F. Shul'gina, the dilutive effect of the Kuban' river can be traced only in a narrow coastal belt not exceeding the width of 1 — 1.5 miles.

The main pest of wood in the Black Sea is T. navalis. The reaction of the Black Sea T. navalis to conditions of decreased salinity have been investigated rather thoroughly. It is known that the larval stage of development is most sensitive to low salinity. According to experimental data by R. K. Pasternak (1958), a normal development of larvae and settlement on wooden objects occurs in water with a salinity not less than 12°/oo. This author has never observed the occupation of wooden objects by larvae in water with a salinity of 11°/oo. Our observations on settlement by larvae in the Sea of Azov confirmed the conclusions of Pasternak, refining the values of salinity at which the penetration of wood by larvae is possible. Near the village of Kuchugura the larvae of T. navalis formed settlements at salinities ranging from 11.26 to 11.51°/oo in July and August 1960.

Mature individuals of T. navalis are less sensitive to low salinity (Soldatova, 1961). A considerable number of young animals 10-12 days old, kept in water with a salinity of 10°/oo for a year preserved the ability of leading a normal life. They reached the size of teredos inhabiting the Black Sea. Their sexual products matured, the larvae were formed in the gill cavity, and they showed normal activity when let out in water. If young teredos are placed in water having a salinity of 8°/oo and kept for a lengthy time period, they perish. The dying occurs gradually and only by the end of the year are all of the test animals dead.

T. pedicellata, the quantity of which in the Black Sea is small, has been found in the Sea of Azov; only mature individuals have been tested with respect to the effect of salinity (Soldatova, in this compilation of papers). The animals kept in water having a salinity of 8°/oo perished in a year. But of those kept in water having a salinity of 10°/oo, 43 percent survived in a year's time. However, the mean size of their body was considerably smaller and the larvae were not expelled.

Only the observations conducted in natural conditions are available for the determination of the limit of salinity for settlement by the larvae of T. pedicellata. Ten individuals of T. pedicellata were found in 1959 in a pile of the wharves of the fisheries plant at the village of Mysovaya; the salinity was about 12-13°/oo in the area.

The same salinity limits have been established for limnorians. In tests, the Black Sea limnorians tolerate a dilution to 12°/oo (Yesakova, 1958). With this salinity, the rate of boring remains the same as it is in the Black Sea water. The eggs lying in the pouch of animals that were kept in water having the salinity of 12°/oo for a year developed normally and the young were produced. Mature limnorians can tolerate for a relatively long time (more than five months) water having a salinity of about 10°/oo The animals continue to bore wood, although the rate of boring decreases almost twice. After a certain time, the cleavage of eggs ceases in the pouches of females and the development of embryos stops.

During the last three to four decades the mean salinity of the Sea of Azov has constantly increased (Fedosov and Vinogradova, 1955; Aksenov, 1955). The salinity data obtained by meteorological stations in various regions of the Sea of Azov confirm the statement.

Let us discuss the salinity regime in the coastal zone of the west coast of the Sea of Azov, because here we can utilize the observations of coastal stations which have been conducted for many years. The most favorable salinity regime for the development of marine borers exists along the Crimean coast of the Sea of Azov and along the Arabatskaya strelka. Thus, in the Mysovaya area (fig. 1, A) the salinity during 1927-1930, 1941, and 1945-1960 has been above 11°/oo, i.e. favorable for the development of T. navalis since 1945. The salinity exceeded 12°/oo during a brief period from 1949 to 1955 and also in 1957 and 1959, making possible the development of T. pedicellata and limnorians. During 1945-1960 the mean annual salinity of water fluctuated from 11.0 to 13.1°/oo. During the four summer months (June-September) the mean salinity was either somewhat greater than the mean yearly magnitude (by 0.2 to 0.6°/oo) or equal to the magnitude. The dilution reached its minimum during 1952-1955, when the salinity did not fall below 12.8°/oo. A certain decrease of salinity was observed during the subsequent years — namely to 11.6-12.2°/oo.

The same salinity conditions were recorded by the meteorological station in the Strelkovoye area (fig. 1, Б). Regrettably, the observations of salinity had been conducted here only from 1948 to 1958; during the entire period the dilution did not impede the immigration of T. navalis, but from 1952 to 1955 also T. pedicellata and limnorians could live in the area. On the average, the yearly salinity value in the Strelkovoye area was 0.5°/oo less than in the Mysovoye area during the period. During the summer months the salinity differences are still smaller. The mean water salinity in the Strelkovoye area for June-September is only 0.1°/oo smaller.

In the Berdyansk area, which adjoins the diluted Taganrogskiy zaliv, one species of marine borers — T. navalis — finds the conditions favorable. The Berdyansk meteorological station conducted salinity observations from 1930 to 1935 and from 1950 to 1960. From 1950 to 1956, as well as in 1958, the salinity in the area was above 11°/oo (fig. 1, B). The mean annual value of salinity during 1950-1956 fluctuated from 11.3 to 11.9°/oo, whereby the highest salinity value was observed in the summer. The mean salinity for June-September of all these years exceeded the mean annual value by 0.2-0.4°/oo. In 1958, the mean annual salinity equalled 10.6°/oo; however, in summer it rose to 11.3°/oo. Consequently, the development of the shipworm was possible in 1958. In all the other years, however, (1930-1935, 1957 and 1960) the dilution in the area was more significant. The mean salinity values for the summer months, like the mean annual salinity values, were below 11°/oo during these years.

In the Zhdanov area of Taganrogskiy zaliv, the salinity of water never allowed the development of marine borers (fig. 1, Г).

In addition to the mean salinity value for a year and for the summer months, the period of minimum salinity during the year plays a significant role in the development of marine borers during the year. As seen from the data listed in Table 1, the greatest degree of dilution in the western portion of the sea is observed during the spring and winter. The total duration of such a period in various years is 1—2, less often 3 months; whereby, within a given year, the periods of intense dilution alternate with periods of increased salinity.

The greatest fluctuations in salinity are observed in the Berdyansk and Strelkovoye areas, the smallest being in the Mysovoye area. But, knowing on the basis of tests the reaction of the Black Sea marine borers to a decrease in salinity, we can assume that such decreases will not exercise a considerable influence on the number of marine borers when they appear in the mentioned areas. However, certain exceptions do occur. Thus, in April 1954 the salinity in the Strelkovoye area was 3.40°/oo. Such an intense dilution brought death to all the marine borers within a year. The mean salinity for January and May 1957 in the Berdyansk area was 8.68°/oo. Such a decrease of salinity for two months in a year may bring death to a considerable number of marine borers. /163

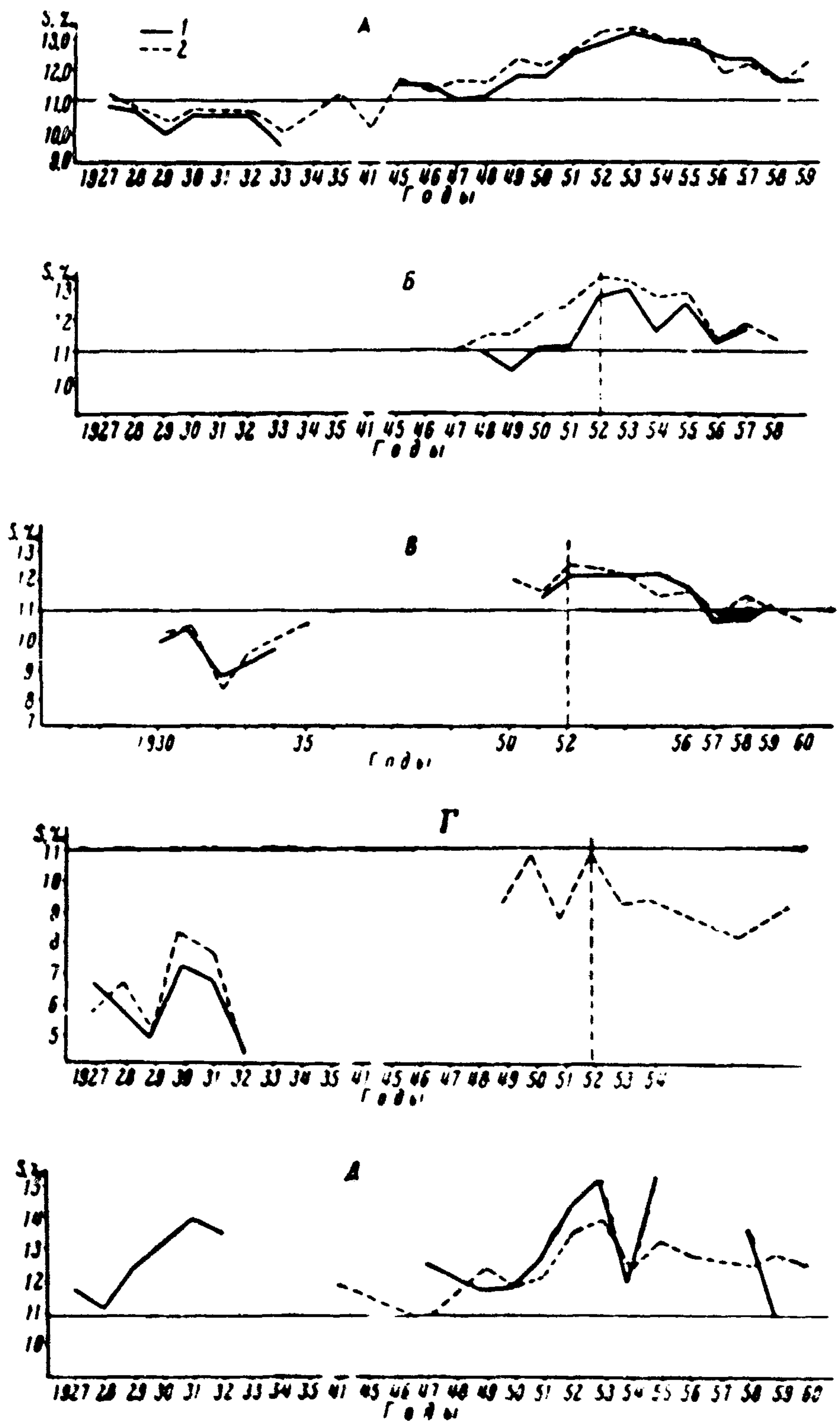

Fig. 1. Salinity of water in certain populated areas of the Sea of Azov (according to data by local meteorological stations).

A — in Mysovoye area; Б — in Strelkovoye area; B — in Berdyansk area; Г — in Zhdanov area; Д — in Genichesk area; 1 — mean yearly salinity; 2 — mean salinity for June-September.

Table 1

Duration of Periods With the Greatest Dilution in Various Areas of the Sea of Azov

Observation point	Year	Mean annual salinity, °/oo	Difference between the mean annual salinity & the salinity of the period of maximum dilution	Months during which the maximum dilution was observed
Berdyansk	1952	11.9	-1.4	Nov
	1953	11.9	-0.8	Jan, Mar, Dec
	1954	—	—	
	1955	11.9	-0.5	Apr
	1956	11.6	-1.4	Feb, Mar
	1957	10.68	-2.0	Jan, May
	1958	10.56	-1.3	Apr
Strelkovoye	1953	13.10	-1.1	Jan, Feb
	1954	11.8	-8.4	Apr
	1955	11.6	-0.9	Jan
	1956	11.4	-1.5	May
	1957	11.8	-2.2	Feb
Mysovoye (mys Kazantip)	1952	12.8	-0.4	Apr
	1953	13.1	-0.9	Mar
	1954	12.9	-0.5	Mar
	1955	12.7	-0.7	Jan
	1956	12.3	-1.0	May, Jun
	1957	12.3	-0.3	Mar
	1958	11.6	-0.4	May, Jun, Dec
	1959	11.7	-0.5	Jan, Feb, Dec

Let us discuss now the characteristics of salinity along the east coast of the Sea of Azov. In August 1951, according to E. F. Shul'gina, the salinity value exceeding 11°/oo was observed only in three coastal areas: (1) north of Temryuk, (2) at the village of B. Zhestera, and (3) south of Primorsko-Akhtarsk. According to Shul'gina, the Kuban' river discharge in 1951 was considerably below the mean yearly value and, consequently, the salinity distribution observed during the year was closest to the pattern that had to be expected after the final regulation of the Kuban' discharge. According to the data of the survey conducted by Shul'gina in August-September 1952, it follows that the salinity in the belt from Peresypskoye girlo (Peresyp Channel) to Taganrogskiy zaliv was below 11°/oo and, consequently, the development of marine borers could not take place.

Table 2

Salinity at Various Points Along the South Coast of the Sea of Azov (°/oo)

Observation time	Golubitskaya	Kuchugury	Mysovaya	Mysovoye (m. Kazantip)
1960				
1 Jul	8.52	11.67	11.20	11.32
5 Jul	9.79	11.24	11.06	11.41
10 Jul		11.24	11.06	11.54
15 Jul	8.79	11.31	11.06	11.68
20 Jul	8.05	11.06	11.24	11.63
25 Jul	10.46	10.50	11.24	11.53
Mean monthly	9.23	11.26	11.19	11.54
1 Aug		11.67	11.29	11.32
5 Aug	10.29	11.31	11.22	11.34
10 Aug	10.61	11.67	11.29	11.39
15 Aug	10.80	11.67	11.29	11.39
20 Aug	11.22	11.04	11.46	11.54
25 Aug	9.63	11.60	11.46	11.55
30 Aug	9.04	11.60	11.46	11.53
Mean monthly	10.77	11.51	11.35	11.44
5 Sep	9.45	12.44		
10 Sep	10.54	12.25		
15 Sep	9.0	10.93		
20 Sep	9.07	10.10		
25 Sep	9.0	10.10		
30 Sep	8.60	11.82		
Mean monthly	9.27	11.27		

Since 1960 we have been carrying out observations on the values of salinity in the most saline part of the Sea of Azov, located in the immediate vicinity of Kerchenskiy proliv: at the village of Kuchugury, lying east of the strait and at the village of Mysovaya, west of the strait. In these areas, the number of <u>T. navalis</u> was considerable for several years. Therefore, it is interesting to observe here the salinity and development of teredos. Also, the observations of salinity have been conducted in the area of the village Golubitskaya, 10 miles east of Kuchugury. T. navalis occurs in the Golubitskaya area only at times and in small quantities. Here, the observations of salinity give an idea on the degree of salinity that obstructs the immigration of teredos. Water samples at three points were taken on the 1st, 5th, 10th, 15th, 20th, and 25th of June, July, August, and September. At Mysovaya such observations were conducted only in July and August. Table 2 lists the data of our observations on salinity which were conducted in the Mysovaya, Kuchugury, and Golubitskaya areas, as well as the data of Mysovoye meteorological station (mys Kazantip).

When examining the data, one may notice a certain increase in the salinity of water from July to August along the coast from Mysovaya to Golubitskaya; however, in Mysovoye (mys Kazantip) the salinity remains at about the same level during July and August. The lowest salinity value during the entire period of observations was found in the extreme eastern point — at the village of Golubitskaya, while the highest salinity value was preserved at the village of Kuchugury. This point, lying in the immediate vicinity of Kerchenskiy proliv, is subjected to the influence of a higher salinity of the Black Sea water.

The salinity data obtained in the Mysovaya and Mysovoye (mys Kazantip) areas in July are to be doubted. Strange is the fact that at Mysovaya, which lies near Kerchenskiy proliv, the salinity is lower than at Mysovoye (mys Kazantip), lying farther from the influence of the Black Sea water. It need be noted that no local reserves of fresh water exist at Mysovaya and Mysovoye. In August, the salinity in both areas was almost the same; and lastly, when we took water samples on September 16 in both of the areas at the same time, it appeared that at Mysovoye the salinity was 11.49°/oo, but at Mysovaya 11.94°/oo. We do not have at our disposal any data that would explain the causes for such a distribution of salinity in July in the Mysovaya-Mysovoye coastal sector.

On the basis of data on the salinity regime of the Sea of Azov, we are in a position to mark the boundaries within which each of the three species of Black Sea borers may propagate. Favorable salinity conditions for the development of T. navalis in the Sea of Azov have been created at this time only in a limited area along the North Caucasian coast (to Kuchugur), along the entire Crimean coast, as well as along Arabatskaya strelka (A. kosa). Along the north coast, the conditions are favorable for the species only in individual years.

The eastern portion of the sea is least favorable for the development of teredo; however, in the years when the river influx is small in the areas, small sectors occur in the area where the salinity allows the infiltration of T. navalis. At Mysovoye (mys Kazantip), the salinity conditions in 1945 did not impede the infiltration of teredos in the area.

T. pedicellata and limnorians can populate still more limited areas — namely, along the Crimean coast and Arabatskaya strelka (kosa).

The instability of the salinity regime in the Sea of Azov, where the greatest salinity exceeds only slightly the lower limit that is favorable to the development of marine borers, will cause frequent changes in the propagation of marine borers. Thus, a small decrease of salinity (1-2$^{\circ}/_{oo}$), caused by a number of years when the continental runoff is considerable, will lead to a sharp decrease in the areas that are available for marine borers, while a number of successive years with limited continental runoff may lead to an increase in the population of borers.

CHARACTERISTICS OF THE THERMAL REGIME OF THE SEA OF AZOV IN SUMMER AND THE REACTION OF BLACK SEA TEREDOS TO THE WATER TEMPERATURE

In order to evaluate the role of temperature that is typical of the Sea of Azov relative to the propagation of teredos and the quantitative population variations that are to be expected, let us discuss the reaction of T. navalis to the variations of the annual water temperature in Gelendzhikskaya bukhta, located relatively near the southern portion of the Sea of Azov.

Here we shall limit our discussion to the water temperature in the coastal belt, insofar as the marine borers that occur in our waters belong to the typical coastal forms, as, incidentally, do almost all of the wood borers in the world.

Observations on the intensity of settlement by larvae of teredos on wooden objects depending on water temperature have been conducted in Gelendzhikskaya bukhta for six years (from 1954-1958 and in 1960). /166
The surface layer of water to a depth of 1.5 m was subjected to investigations because the main quantity of larvae T. navalis, which is sometimes mixed with small portions of the rare and unnoticed T. pedicellata (Ryabchikov and Nikolayeva, in this compilation of papers), settles in this layer.

The wooden panels were replaced in each ten-day period, not each month as is usual, which made it possible to specify the beginning and the end of the settlement period, and to determine more accurately the relationship between the temperature of water and the quantity of larvae occupying the panels. In almost all of the years, the settlements occurred in a brief time after the temperature had reached 20° C and began to rise higher. Therefore, in June, when the mean temperature did not exceed 20° C or was a little below the value, the settlement was either not observed or, in rare cases, only fractions of 1°/₀ of the total number of larvae settled in the entire summer period. The season of settlement lasted four months or a little more, from July through October, inclusively; in warm years, the process took place also in November, but the quantity of larvae occupying wooden panels during the month was very small. The end of the settlement process usually coincided with the drop of temperature to 15° C.

The quantity of larvae that had formed settlements in the warm season varied very much from year to year. It changed with changes of temperature; a rise of the mean temperature in four summer months (June-September) by 1.0 to 1.5° C led to variations in the order of magnitudes expressing the rate of settlement.

The investigated period includes two years with a cool summer, when the mean temperature was 22° C (1956, 1958), and approximately 150 to 400 larvae occupied 1 dm^2 in each summer; two warm years when the mean summer temperature was 23° C and more (1954 and 1955), and when the number of settled larvae reached 900 per 1 dm^2; and one intermediate year when the mean summer temperature was 22.5° C (1960), and the number of larvae occupying 1 dm^2 was about 500. The warm year of 1957 stands out in this period, although its mean summer temperature was nearly 23° C yet it cannot throw light on the unusually sharp increase in the number of settled larvae — more than 4000. This number exceeds more than four times the value reached in the summers of 1954 and 1955, which were as warm as that of 1957.

The unusually intense settlement by larvae in 1957 depends upon the peculiar impact of the relatively high temperature on the reproduction process of teredos, which is manifest in the mean arithmetical value of temperature for all of the summer months. As demonstrated by data of the same investigation, a uniform temperature variation during all of the summer months, at the same mean quotients, leads to a smaller sum of settled larvae than in the case of a high temperature for only two months. The most intense settlement process of larval teredos in Gelendzhikskaya bukhta occurred, as a rule, at the temperature of 24 or 25° C.

The smallest amounts of settled larvae were observed in years when the mean water temperature of about 24° C and more was observed only in one month (1956 and 1958); the mean rate of settlement pertains to years when a high temperature lasted two months (1954, 1955, and 1960); lastly, in 1957, when a high temperature lasted three months in a row, the quantity of settled larvae was the greatest, exceeding 27 times the minimum of 1956.

The fact that, when a high temperature was observed during just one month, more than half and even two-thirds of the total settlements established in the warm season pertain to this month is also typical. A high temperature lasting two months results in 75-80 °/₀ of settlements, and only in one case they constituted slightly more than one-half, but in 1957 almost the entire mass of larvae established settlements on wooden panels within a three month period. We did not find any connection between the water temperature in the cold season of the year and the size of the subsequent larval settlements.

The regularities observed in Gelendzhikskaya bukhta permit us to underline, with a high degree of probability, the role of water temperature in the development of T. navalis population in the Sea of Azov. Let us compare, first of all, the temperatures of the summer

Table 3

Mean Water Temperature in the Summer Period

Place where samples were taken	1954	1955	1956	1957	1958	1960
Gelendzhikskaya bukhta.	23.9	22.9	21.7	23.1	22.2	22.5
Arabatskiy zaliv.	23.2	22.3	21.2	23.0	21.5	22.0

season (June-September), in the years that we discussed in detail, in Gelendzhikskaya bukhta of the Black Sea, on the one hand, and the temperatures in Arabatskiy zaliv of the Sea of Azov, on the other hand.

As seen in Table 3, the years with warm and cool summers in the Sea of Azov alternate in the same order as in Gelendzhikskaya bukhta. Thus, we have a possibility of comparing the status of the teredo population in the same year in two neighboring seas. Further, we have to remember, however, that the mean water temperature in Arabatskiy saliv is, in summer, approximately 0.5° C below that in Gelendshikskaya bukhta.

Table 4

Mean Monthly Temperature of a Cool and a Warm Summer

Place where samples were taken	Months			
	VI	VII	VIII	IX
	1956			
Gelendzhikskaya bukhta.	19.9	22.5	24.0	20.6
Arabatskiy saliv.	20.0	22.5	23.4	19.0
	1957			
Gelendzhikskaya bukhta.	20.0	24.0	24.3	24.1
Arabatskiy saliv.	21.0	24.4	24.8	21.7

In order to elucidate the local differences in the extreme years, let us compare the mean monthly temperatures of the cool summer in 1956 and the temperatures of the exceptionally warm summer in 1957 (Table 4).

As seen in Table 4, the mean monthly temperature for August and September in the cool summer of 1956 was somewhat lower in Arabatskiy zaliv than in Gelendshikskaya bukhta. However, in the warm summer of 1957, the water temperature in the Sea of Asov was higher, almost throughout the summer, than in Gelendshikskaya bukhta, and only in September did the temperature drop considerably, differing from that of Gelendshikskaya bukhta by 2.4° C. /168

Let us add that the summer temperature of the remaining years of the last decade differs little in these areas, except for September, which is always colder in the Sea of Asov. Here the autumn arrives at least one month earlier, which shortens by one month the period of mass settlement by larval teredo. High summer temperatures (24–25° and more) are observed for one or two months, usually in July and August. Thus, even if the period of settlement by larvae is somewhat reduced, the heat regime of the Sea of Azov gives the animal two months with high water temperatures, which furthers a mass development of the species.

Very little is known about the influence of temperature on T. pedicellata. However, in the exceptionally warm summer of 1957 the species was found more often, than during all of the remaining years. In the warm Mediterranean waters the species more widely distributed than in the colder Black Sea. Along the North American coast in the Atlantic Ocean, the area populated by T. pedicellata partly overlaps the southern half of the area populated by T. navalis; however, on the whole, the area lies south of the area occupied by the latter. Generally, T. pedicellata is more thermophilic than T. navalis. The conditions in the Sea of Azov are less favorable for the species than the conditions in the Black Sea.

T. utriculus is more often found in places where the upwelling of cold bottom waters takes place as a result of offshore winds, making the water cooler in summer and warmer in winter. This species is rarely found in the Sea of Azov, where the conditions of the thermal regime are in contrast with its ecological requirements.

ON THE PRESENCE OF WOOD IN THE SEA OF AZOV AS A MATERIAL NECESSARY FOR MARINE BORERS

In the Sea of Azov, which was not inhabited by borers until the 50's, almost all of the hydrotechnical structures were and are being built of wood, which is not at all protected from marine borers. The unprotected wooden structures, piles for nets, or simply sunken logs and fragments of boards are now becoming a potential base for the development of borers, and these can further their propagation in the water basin.

During the expedition in 1960, which was carried out by the collaborators of the Institute of Oceanology on the survey ship "Obruchev" with a view to elucidating the existing distribution of marine borers in the Sea of Azov, all the wooden objects that are constantly in the water along the south coast of the sea from Golubitskaya station to Arabatskiy zaliv, inclusively, were accounted for, as much as possible, in detail. There are no large ports in the southern part of the Sea of Azov. The bays are frequented by small fishing vessels and they are equipped with small wharves, the base of which consists of 20-60 piles. Altogether, two wooden wharves are in the Temryuk-mys Akhilleon sector more than 30 miles apart; both are situated at the Golubitskaya station, the total number of piles being about 90. Several years ago, only one small wooden wharf was at the village of Kuchugury. The wharf was heavily damaged by marine borers when it was investigated in 1958. Even then the piles of the wharf could be broken with a strong push of the hand. At the present the wharf does not exist; however, part of the stumps of the old piles has remained.

Only one wharf, consisting of about 60 piles, is found west of Kerchenskiy proliv to mys Bogatube * (about 15 miles).

No wharves or other wooden structures are found in the mys Bogatube — mys Chagany * sector which is about 10 miles long. The total number of piles in Kazantipskiy zaliv is about 50. A relatively great number of wharves is found in the mys Kazantip—village Mysovoye sector of Arabatskiy zaliv. The total number of piles exceeded 200 in a relatively small coastal sector five to six miles long. The coast of Arabatskiy zaliv is almost devoid of wooden structures.

As seen from the outlined review, the quantity of wooden structures in the southern part of the sea is small. Each of them is insignificant in size and, in addition, they are located at a great distance from one another.

In addition to wharves based on piles, much wooden material is used in summer in the Sea of Azov in the form of piles for stationary nets. These piles are, as a rule, in the water only for a limited period (since 1955 the catching of fish with such nets is forbidden from 1 May to 1 September). However, sometimes the piles stay in the water throughout the summer and are taken out only in the late autumn. In such a case, as demonstrated by our observations, the marine borers have a chance to mature in wooden objects and develop pelagic larvae. However, fishing with stationary nets has been greatly limited during the last years. From 15 to 20 nets are placed at the present time in the area we investigated.

In addition to the wood brought by man into the sea in the form of port structures, wooden enclosures, and vessels, there are large quantities of sunken and floating wood brought into all of the seas by rivers. A special inquiry of the commanders of fishing trawlers, working along the Caucasian coast of the Black Sea (Ryabchikov, 1957), demonstrated that large quantities of sunken wood are found at various depths along the entire Caucasian coast. This stock is constantly supplemented by numerous mountain rivers. Such wooden materials float for a while in water, then they are either cast ashore, or become waterlogged and sink to the bottom of the sea. As the larvae of marine borers are always present in the water, the floating and sunken wood becomes gradually infested with them and constitutes a center of their propagation.

In addition to other favorable conditions, the concentration of larvae depends on the quantity of sunken wood. The floating and sunken wood create conditions for the existence of marine borers outside the ports, serving as a means of their propagation. In some cases, the sunken wood plays the same role in the propagation and increase of the number of borers, as do the vessels and port structures.

In order to solve the problem on the propagation of borers into the Sea of Azov and on the formation of individual constant infection centers in various areas of the sea, it is necessary to obtain information on the presence of various wood material in the sea.

As demonstrated by inquiries of population and direct examination of the coast in the Solyanoye—Golubitskaya sector, very little wood is found along the south coast of the sea.

The other coastal sectors of the Sea of Azov, which are surrounded by steppes, are also almost devoid of drift wood. Among the material cast ashore by storms one can seldom find fragments of boards, oars, or /170 boxes here. The numerous tributaries of the Kuban' flow across mountainous and forested areas, collecting of course a considerable quantity of wood, but the material remains in the plains of the river estuary and in the shallow areas overgrown with reeds so that it does not reach the sea. Thus, only the wood constituting the underwater parts of structures can serve as a material for use by marine borers. The hulls of vessels with plank coatings play a smaller part in this respect.

If only a few small platforms and wharves occur along the south coast of the sea, the west coast along Arabatskaya strelka is devoid of any permanent structures. As to the structures existing in Taganrogskiy saliv and Temryukskiy saliv, they need not be taken into consideration; this is to a degree true of the structures existing in the diluted waters along the east coast: they are completely protected from attacks by the shipworm. A serious danger, indeed, is represented by the unprotected wood in a relatively small sector between Genichesk and Berdyansk, inclusively. These are the piers at Genichesk and Berdyansk, a few relatively large pile structures for fisheries and, lastly, the coastal barriers requiring large quantities of hydrotechnical wood. It need be added that the wooden fishing vessels that are moored at the wharves of fisheries may serve as the distributors of shipworms.

On the basis of what has been said above, we can consider that it is here, along the indicated sector of the north coast, that the appearance of the first powerful centers of propagation of shipworms and the outburst of their destructive activity are to be expected with the presence of appropriate salinity. In conjunction with this, it is necessary to replace immediately the unprotected wood in structures with creosoted wood.

The piles used for holding nets are in the sea only during the summer season. The shipworms infesting the wood, say in July, reach their sexual maturity in only four weeks, producing a small number of young. In the autumn the piles are taken out and the animals living in them perish. For all that, these piles play an important role due to their great numbers. Often they are placed near the coast; each net requires 20-30 piles. Inhabiting them annually, the shipworms develop a considerable quantity of larvae by the end of the summer. The only means of eliminating this danger is the building of nets without the wooden piles, the more so, because the protective means lose their effect when the piles are out of the water.

THE RESULTS OF EXAMINATION OF WHARVES AND PILES OF NETS

The wharves and piles of nets in the coastal belt of the Sea of Asov (Fig. 2) were investigated during 1958-1961. Usually, several wharves and piles of nets were examined in each locality. Besides, the investigation of the wooden material removed from the sea was conducted differently, depending upon the fact of whether or not they contained traces of damage. If a visual examination did not disclose traces of damage, a number of segments were cut off at distances of about 50 cm from one another. The segments were split into thin splinters, which /171 were then examined with the aid of a magnifying glass. If no traces of damage were found, the given structure was considered to be free of the shipworm.

The investigation of wood on which signs of shipworms were found was conducted by a somewhat different method. The piles of wharves and nets were cut into pieces 0.5 m long, counting the number of burrows made by shipworms at the ends of each segment; then the length of burrows was measured and the number of live mollusks and their species were determined; in addition, the condition of the lining in the empty burrows was examined.

In four years we investigated the entire south coast, west coast, and part of the north coast (from Genichesk to Berdyansk) (Table 5). The most detailed data were obtained along the south coast from village Golubitskaya to mys Kazantip. In this area, the wood samples were obtained each year. Live individuals of T. navalis were constantly found

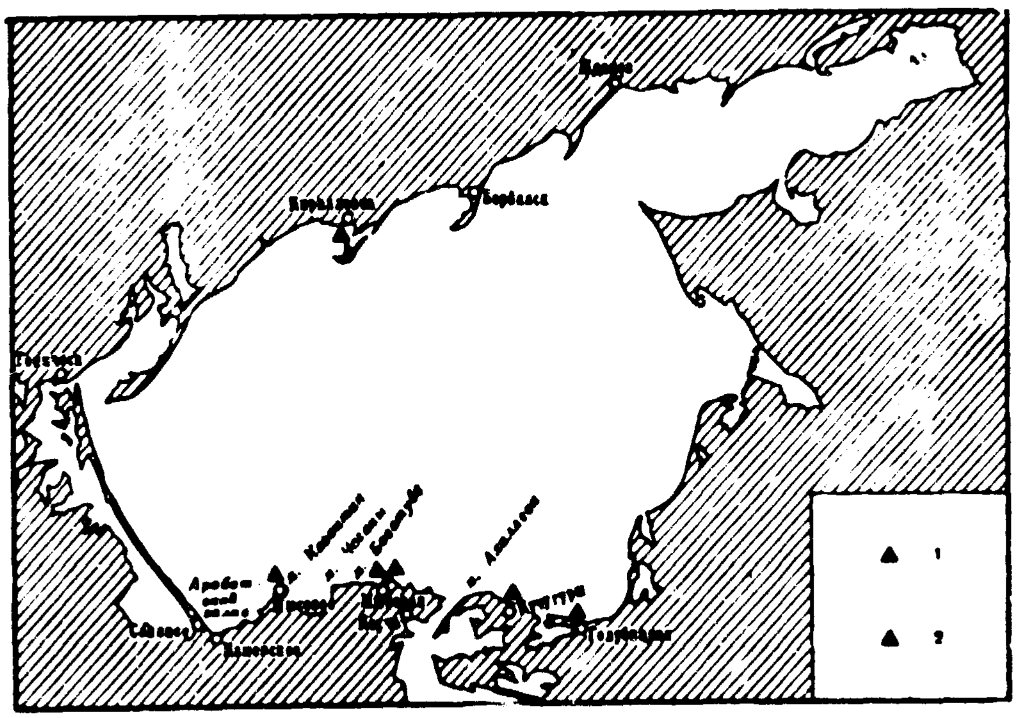

Fig. 2. The distribution of shipworms Teredo navalis (1) and T. pedicellata (2) along the coast of the Sea of Azov.

Geographical names (clockwise beginning from extreme left):
Genichesk - Kirillovka - Berdyansk - Zhdanov - Golubitskaya - Kuchugury - m. Akhilleon - Kerch' - Mysovaya - m. Bogatube - m. Chagany - m. Kazantip - Mysovoye - Arabatskiy zaliv - Kamenskoye - Solyanoye.

only in piles at the villages of Kuchugury, Mysovaya, and Afanas'ino. In the first two locations, the rate of wood destruction reached the intensity encountered in some areas of the Black Sea; in 1959, a pile in the wharves of Mysovaya contained, in addition to two T. navalis specimens, 10 live T. pedicellata specimens. Only one specimen of T. navalis was found at the village of Afanas'ino. Seldom was T. navalis found at Mysovoye (mys Kazantip) and Golubitskaya. In both of these places the wood had been attacked by the shipworm prior to our investigation (1957), because only empty burrows were found.

Table 5

Analysis of Piles of Wharves and Nets Removed from the Sea of Azov

Observation point	Year of observation	Elements of structures	Length of use of piles of wharves and nets, years	Depth in the place of observation, m	Length of segment cut off, counting from sea surface, m	Diameter of segment, cm	Width of damaged area, cm	Number of burrows at the end of segment	Presence of live teredos, length of their burrows	Maximum length of burrows, mm	Minimum length of burrows, mm	Maximum diameter of burrows, mm	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Berdyansk	1958	2 piles of a wharf	Not less than 10	2	1.2 1.7					No damage			The pile was extracted from the bottom on 9-13-59.
Berdyansk	1961	3 piles of a wharf	About 5	4	0.5 1.0					Same			Cut into segments on 6-10-61.
Kirillovka	1961	6 piles of a wharf	Not less than 5	5	4.5	24	24		No	120			Piles were extracted from the sea in autumn 1960 and remained ashore during winter, spring and summer 1961. The lining of burrows was well preserved. The burrows were clean.

Table 5 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Genichesk	1960	5 piles of a wharf	About 5	4	0.5 1.0 2.5 3.5					No damage			Fragments were chopped off all-over the surface of 4 piles at distances of about 0.5 m. The pile was extracted from bottom on 9-7-60.
		1 pile of coastal fortification	About 50	0.7	4.0								
Solyanoye (Arabatskiy zaliv)	1960	8 piles of a wharf	2-5	3-4	0.5 1.5 2.5 3.5 4.0					Same			Of 8 examined piles 6 were taken ashore and were not in the sea in 1960; 2 piles were extracted from the bottom on 9-12-60. Samples were taken from all the piles.
Kamenskoye	1960	3 piles of a wharf	2-3	1-2						Same			The piles were not extracted from the bottom. Splinters were obtained from all the piles.
Kamenskoye	1960	5 piles of nets	7-10	4-5						Same			The piles were not put into the sea in 1960.

Table 5 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Semenovka	1960	1 pile of a wharf	2-3	1.5					No damage				Pile was extracted from bottom on 9-11-60. Splinters were obtained.
Mysovoye (Arabatsk-iy zaliv)	1958	1 pile of a wharf	5	2					Same				Extracted from bottom on 9-15-60.
Mysovoye (Arabatsk-iy zaliv)	1959	lath	1	2									Had been in water from 10-12-58 to 9-16-59.
Mysovoye	1960	2 piles of a wharf	2-3	2	0.5 1.0 1.5								The piles were extracted on 9-6-60.
Mysovoye	1960	2 piles of a wharf	2-3	1.0-1.5									Segments were cut off on 9-6-60.
Mysovoye	1960	pile of a wharf	5				5.0	6	No				The pile had been in water 5 years. 5 years ago had been taken out of water and used as a support in the underwater part of a bridge of fishery plant. The pile was examined on 9-11-60.

Table 5 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mys Kazantip	1958	pile of nets	Not less than 5	4-5		18.0	5.0	4	No	12.5	5	6	Lining in all burrows was well preserved. The pile was taken out of the sea in the autumn of 1957.
Zolotaya (Kazantipskiy zaliv)	1960	pile	4-5	1.5	1.0	19.0		2	No	80	6	6	Lining in all burrows was well preserved. The pile extracted from the sea on 9-13-60.
Afanas'ino	1958	pile of a wharf	2	0.5	0.5	10.0		1	1	110		5	The pile was taken out of the sea on 9-15-58.
Mysovaya	1958	pile	4-5	1	0.8	35.0	7.0	6	135 246	250	12	11	Lining was well preserved in all the burrows. The pile was extracted from the bottom on 9-16-58.

Table 5 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mysovaya	1958	pile of a wharf	4-5	1	1.0			11	No	480	160	10	A piece of pile given us for examination by the fisheries plant. The greater part of burrows had a well preserved lining. Some burrows did not have the lining. The pile had been extracted from bottom in spring 1958. The examination took place on 9-16-58.
Mysovaya	1958	pile of net	5	4-5	4.0 4.5 (the deepest end)	17.0 16.0	5.5 6.5	4.7 98	No No	210 230	30 40	9 9	The greater part of burrows had a well preserved lining. Some burrows without lining. The pile was not in water in 1958. The examination took place on 9-16-58.

Table 5 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mysovaya	1959	pile of a wharf	About 5	2	0.5 1.0 1.5	17.0 17.0 17.0	6.0 6.5 8.5	11 81 156	92	350 367	1 2	10 10	The pile was extracted from bottom on 9-17-59. Some burrows had well preserved linings, others were filled with sand and mud.
Mysovaya	1960	pile of a wharf	3	1.60	0 0.5 1.0 1.5	19.0 19.0 18.5 19.0	0 6.0 7.0 9.0	0 31 50 117	15	370	38	10	The pile was extracted from bottom on 9-16-60; the damage was so great that the pile broke at the bottom when lifted. Many live organisms were seen but only 15 were extracted from the wood.
Kuchugury	1958	pile of a wharf	Not less than 5	1.20	0.5 1.0	18.0 19.5	4.0 4.5	153 164	No	210 325	32 30	7.5 0.8	Some burrows had a well preserved lining, others lacked it. The pile was extracted from the bottom on 9-9-58.

These are the only points along the south coast of the Sea of Azov where the shipworm was found. No traces of damage were found on the piles of wharves at Temryuk, lying 10 miles east of Golubitskaya. Neither were the shipworms found when examining the piles of wharves and nets in the areas of Semenovka, Kamenskoye, and Solyanoye, which lie west of mys Kazantip.

No wooden structures exist along the Arabatskaya strelka on the west coast as far as Genichesk. The Genichesk harbor appeared to be free of marine borers. A piece of wood heavily damaged by the shipworm was found at Kirillovka on the north coast. The wharves at Kirillovka were examined in August 1961, about eight months after they had been extracted from the sea. Palettes of T. navalis were found when the burrows were opened. Judging from the well preserved calcareous lining of burrows, the wood had been settled by larvae in the preceding year and the destruction had taken place during the summer and autumn of 1960. The piles of wharves in the Berdyansk harbor did not contain any traces of damage.

Thus, two species of shipworms — T. navalis and T. pedicellata — have at present settled in the Sea of Azov. The first of them appeared to be more widely distributed and more numerous, inhabiting the coastal zone from Golubitskaya to Mysovoye (mys Kazantip). Even if salinity conditions are favorable, one cannot observe the settlement by larvae in the periphery of the area each year. The finding of T. navalis at Kirillovka is a special case. Teredos have appeared far from Kerchenskiy proliv, and the intermediate centers of propagation are absent. The same phenomenon was observed in 1951 in the Black Sea where T. navalis appeared in a large sector in a low salinity area, damaging the bottom segments of net piles at Ochakov. Of course, the larvae are transported by the saline water of compensatory bottom currents.

RESULTS OF REGULAR OBSERVATIONS ON SETTLEMENT BY LARVAE OF THE SHIPWORM ALONG THE SOUTH COAST OF THE SEA OF AZOV

As a result of an investigation of piles of wharves and nets during 1958-1960, some idea of the distribution of marine borers in the Sea of Azov and their species composition was obtained. However, the data yielded only an approximate idea on the duration of the period of settlement by larvae and on their quantitative distribution during the period. In order to elucidate the problems, regular observations on settlement by the larvae of the shipworm along the south coast of the Sea of Azov were begun in the summer of 1960 at villages Mysovoye, Mysovaya, Kuchugury, and Golubitskaya. Wood is heavily damaged by shipworms at Mysovaya and Kuchugury, while at Mysovoye and Golubitskaya the larvae do not, by any means, appear every year. Thus, the distribution of marine borers in these locations makes it possible to determine the sea areas where teredos propagate in mass and the status of their population on the peripheries of the inhabited area.

Pine wood boards, 75 x 15 x 2.5 cm in size, were submerged in all the four locations. Two such boards were submerged vertically in the sea on the first of each month. At the beginning of each subsequent month the boards were taken out and replaced by new ones. The boards were fastened with nails, each separately, to wooden piles of wharves, whereby the upper end was 0.5 m below the sea surface, while the lower end was at a depth of 1.2 m. The bottom depth of locations where the boards were submerged — namely, at Mysovaya, Mysovoye, and Golubitskaya — was about 2 m (1.7—2.2 m). At present there are no wharves at Kuchugury; only a few piles protected by metal tubes are at a depth of 0.8—1 m. Boards were fastened to the piles with the aid of wires. No other wooden structures were found in Kuchugury to which the boards could be fastened.

Because the side of the board facing the pile did not adjoin the latter, the larvae penetrated the board also from this side. Therefore, the counting of larvae per unit surface (1 m^2) was based on the entire surface of the board. The counting was aided with binoculars, and a mark was made at each burrow. The board was then split into chips, and the length of burrows made by all of the recorded animals was measured; also the species of the borers was determined. /176

As seen from Table 6, the larvae had established settlements only at Kuchugury. Besides, only the larvae of T. navalis were observed.

The larvae settled during all of the three months of observations — July, August, and September. The damage to the wood by the shipworm was insignificant during this time. Even in July, when the greatest number of larvae settled, one animal was, as a rule, found on 13—14 cm^2. By the end of the season — in September — only a single larva of T. navalis had settled on the board whose total area constituted 2600 cm^2. In July and August, we found in the boards animals that had made burrows ranging from fractions of a millimeter to 12 mm. There is no doubt that such a diversity of sizes indicates that the larvae had occupied the wood during an entire month, in July as well as in August.

Table 6

Results of Regular Observations on the Settlements of Larvae of the Shipworm Along the South Coast of the Sea of Azov in the Summer of 1960

Place of observation	Number of individuals of shipworms occupying 1 dm^2 in 1960		
	July	August	September
Mysovoye (m. Kazantip). . .	0	0	0
Mysovaya.	0	0	-
Kuchugury	7	0.5	One animal in the board
Golubitskaya.	0	0	0

CONCLUSION

The investigations that have been carried out heve established that some of the species of the marine borers inhabiting the Black Sea have already settled in the Sea of Azov; it can be assumed that this had happened not later than the middle of the last decade.

Of the five species of marine borers found in the Black Sea, only two have entered the Sea of Azov - namely: T. navalis and T. pedicellata. During three years of observations reliable traces of T. navalis have been found along the south coast of the Sea of Azov from mys Kazantip in the west to Temryuk in the east (St. Golubitskaya). No traces of damage to wood have been observed in Arabatskiy zaliv and along Arabatskaya strelka. As to the north coast of the Sea of Azov, T. navalis has been found only at Kirillovka. Its distribution to the north of the Kuban' estuary is not too probable. East of the strait, T. navalis was constantly found only at Kuchugury; west of the strait it was found /177 only at Mysovaya. In both of the locations the damage to wooden structures reached the level observed in the Black Sea. T. pedicellata was observed only once in a small quantity at Mysovaya.

The appearance of marine borers in the Sea of Azov is associated with an increase in salinity to a level corresponding to their ecological requirements. This rise in salinity was caused, first of all, by climatic conditions; during the last decade, in addition, the phenomenon was intensified by a decrease in the discharge of Don and Kuban' waters in connection with large hydrotechnical structures and the use of water of the rivers for irrigation.

A comparison between the temperature of the water of the Azov and Black Seas leads to a concl ion that, in the Sea of Azov, the water temperature in summer months will further a continued increase in the number of individuals of the species and their continued spreading, although the season of mass attacks on wood will be somewhat briefer than, for instance, along the Caucasian coast of the Black Sea.

A decisive factor in the spreading of marine borers is the presence of the needed material — the wood. As to the Sea of Azov, this factor is extremely unfavorable with respect to the development of population and the further spreading of marine borers. In contrast to the Black Sea, natural reserves of wood are lacking here, while to the Black Sea the wood is supplied by rivers flowing through forested mountain slopes. Also the number of stationary wooden hydrotechnical structures is small in the Sea of Azov. In addition, the small wharves are removed in winter. The number of stationary nets with supporting piles has considerably decreased during the last years, while the new models of the nets do not use wood at all for coastal fishing. This circumstance inhibits considerably the development of potent centers of marine borers, where they could exist for a number of consecutive years and from where they could progress into other areas.

Inasmuch as the process of salinification is slow and fluctuating, and the quantity of objects for settlements is insufficient, the further spreading and intensification of destructive activities of teredos in the Sea of Azov will occur at a slow rate. However, in certain years that are very favorable to marine borers, as well as in periods of several years, one may expect an explosion of their development in various places, which will lead to a rapid destruction of wooden structures. Remembering this, it is necessary to use only treated wood in the hydrotechnical structures that are built from now on.

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SETTLEMENTS OF LARVAE OF THE MARINE BORER TEREDO NAVALIS L. (MOLLUSCA, TEREDINIDAE) AND THE TEMPERATURE OF WATER IN GELENDZHIKSKAYA BUKHTA OF THE BLACK SEA

Abstract

The settlement on wood of the larvae of Teredo navalis L. in relation to water temperature has been studied during 1945-1958.

A minimum settlement of larvae was observed at temperatures not less than 20° to 21°; mass settlement occurred at a temperature ranging from 24° to 27°.

The quantity of larvae settling during the summer depends on the duration of periods with optimum temperatures; if a mean monthly temperature of no less than 24° lasted only one month, the settlement was slight; with a two month period of this temperature the settlement was six times more intensive, and with three months of optimum temperature the intensity of larval settlement increased 27 times. The peak of settling occurred at the end of a period of optimum temperature.

This characterizes Teredo navalis L. as a relatively thermophilic species.

The intensity and dates of settlement of larvae of the shipworm were studied during five consecutive years (1953-1958) in Gelendzhikskaya bukhta of the Black Sea. In the investigation we utilized pine boards, 10 x 5 x 2 cm in size, placed under the wharf of Gelendzhikskiy port and replaced each ten-day period beginning from June to November, inclusively. The boards were suspended by weights, two at a point, 1.5 m below the surface of the water. Although three species of shipworms are found in this area, we consider that the data are applicable to T. navalis L. because the species dominates here. The other species — T. pedicellata Quatrf. — is observed only as a rare and quantitatively insignificant accomplice with the former. The third species — T. utriculus Gmelin. — inhabits slightly deeper strata and is also rarely found; in the test boards submerged in the upper water layer it was never observed.

A small depth of submergence was selected not only for the purpose of avoiding the admixture of T. utriculus, but also for other reasons.

According to observations of fishermen, light piles used for fastening nets in the Novorossiysk-Sochi sector are broken by waves by the end of the warm season as a result of damage by the shipworm, which accumulates in the upper 1-2 m water layer. The upper end of the underwater part of the net pile to a depth of 1 m or more is usually little damaged, because even a weak wave motion creates in the layer conditions that are unfavorable for the settlement of larvae. Thus, the obtained data characterize the depth level at which the greatest danger exists for wooden structures.

The results of five years of observations are presented in Table 1.

The larvae establish settlements on wood in a period of four to six months. The wood is occupied during the greater part of the warm season of the year, beginning from July, less often from June, after the water temperature has reached 20° C or more. The earliest occupation of wood was observed in 1954 in the first ten-day period of June, which is associated with an earlier warming of the water. The latest occupation was observed in 1957, it began in the second ten-day period of July; in the first ten-day period of the month the temperature was about 21° C.

In almost all of the years, during which the observations were conducted, the larvae began to establish settlements in rather great numbers. Evidently, the action is associated with a sharp rise of water temperature to 23-24° C in the first or second ten-day period of July. The process was slow only in July 1956, when the water temperature during the first ten-day period of the month was only 20° C. /181

The number of settling larvae decrease abruptly in November, ceasing as a rule in the second ten-day period of November. In 1956 and 19[illegible] the settlement ceased in the last ten-day period of October, which was associated with a colder hydrological summer and an early cooling of water. By the end of the season, the larvae settle on wood at a lower temperature than in the beginning. However, when dealing with the mean temperatures of days and ten-day periods, one must admit that, in individual days, the actual temperature of sea water during the daylight hours can be higher than the mean temperature of ten-day periods. In such cases one may expect a temporary increase in the ciliary activity of some of the larvae. The number of larvae beginning to bore wood remains noticeable at a temperature of [illegible]° C and even a little below 19° C. Single larvae occupy wood when the mean

Table 1

Number of Larvae of T. navalis L. Occupying 100 cm^2 (A) in warm Seasons and the Water Temperature (Б)

	Month and Ten-day Period																		Entire warm season
	VI			VII			VIII			IX			X			XI			
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1954 г.																			
A	1	0	1	57	49	19	46	245	63	83	219	27	10	22	27	11	7	0	892
Б	19,5°	22,1°	24,3°	28,4	27,4°	25,2°	24,3°	25,3°	28,2°	23,0°	23,7°	22,4°	19,3°	13,5°	19,1°	17,0°	16,9°	14,3°	
1955 г.																			
A	0	0	0	12	5	25	208	462	14	14	22	15	92	—	19	38	7	0	931
Б	18,1°	20,8°	21,8°	24,7°	23,7°	25,8°	25,6°	22,2°	23,6°	23,5°	23,3°	21,8°	21,9°	20,6°	19,6°	26,7°	15,4°	12,8°	
1956 г.																			
A	0	0	0	2	0	17	34	22	38	6	1	1	26	0	1	0	0	—	148
Б	17,9°	21,0°	20,9°	20,1°	23,3°	24,1°	24,6°	23,1°	24,5°	23,1°	21,0°	17,8°	19,7°	15,0°	15,3°	12,4°	11,0°	9,1°	
1957 г.																			
A	0	9	0	0	70	64	46	780	100	1050	1800	34	49	—	20	2	0	0	4015
Б	17,3°	20,7°	22,2°	21,0°	25,5°	25,5°	20,9°	25,2°	26,7°	25,7°	24,8°	21,8°	19,2°	13,8°	16,3°	16,5°	14,2°	14,2°	
1958 г.																			
A	0	0	0	1	40	14	2	22	203	4	33	—	42	31	4	0	—	—	396
Б	20,6°	19,4°	23,1°	23,0°	22,4°	23,2°	23,2°	23,6°	25,6°	20,4°	20,7°	20,5°	18,7°	18,1°	15,5°	16,4°	14,6°	9,5°	

temperature of a ten-day period is about 16° C; when the temperature slightly exceeded 14° C, the settlement by larvae was not observed.

Extremely sharp yearly fluctuations in the number of larvae occupying wood draws our attention. If in the first two years of observations, the numbers were similar and high - about 900 per 100 cm^2, in 1956 the number was very small, 6 times less. In 1957 the number of settlers increased 27 times in comparison with the lowest value, but in the following year it decreased again ten times.

Such fluctuations cannot be explained by differences in the duration of the warm season. Indeed, in 1956 and 1957, the settlement periods were equal - four months, while the intensity of occupation differed 30 times. On the other hand, in 1954 the settlement period was longer by one month than in 1957, whereas the quantity of settlers was four times smaller.

As is seen, the duration of settlement period alone does not play a noticeable role in the formation of the yearly population of teredos. The broadening of the biological season, if it occurs, takes place either by adding November, in case of an extremely warm autumn, or June, in case of an early spring. However, the number of settlers in November is small, while in June only single individuals occupy wood.

It is known that the salinity along the Black Sea coast far from estuaries of great rivers is about 18‰, and it fluctuates little, not exercising any influence on the population numbers of teredos. The main factor, upon which the intensity of occupation by the shipworm depends, appears to be the temperature. Table 2 shows the total numbers of settled larvae of teredo in comparison with the water temperature for the entire warm season, beginning with the first appearance of larvae on the test panels and ending with a complete cessation of occupation in each year; in addition, the number of larvae and the mean water temperatures for the hydrological summer only (July-September) are listed.

The first comparison presents a direct relationship between the water temperature and the number of settled larvae; but on the basis of temperature of the settlement period, all the observation years can be divided into two groups only: years with cool summers (1956 and 1958), unfavorable for teredos, and warm years, favorable for teredos (1954, 1955, 1957). Differenc between the mean temperature of the settlement period is only 1.5 for these groups. Besides, it is impossible to explain, with the aid of temperature, the great differences in the numbers of settled larvae between the years with intense and very intense settlement formations, 1954 and 1955, on the one hand, and 1957 on the other hand.

Attempts to compare the sum of settled larvae and the mean water temperature during the hydrological summer (July-September) in various years disclosed that the greater part of the yearly teredo generation pertains to these months - namely 4/5 to 9/10 and more. The fact stands

Table 2

Water Temperature and the Number of Larvae of _T. navalis_ L. Occupying Wood

	Years of observations				
	1954	1955	1956	1957	1958
Mean water temperature during the settlement of larvae of teredo, °C	22.5	22.1	21.0	22.3	21.3
Number of larvae occupying 100 cm^2 during the entire warm season (100%).	892	931	148	4015	396
Mean water temperature for 3 summer months (July-September), °C.	24.6	23.9	22.4	24.2	22.6
Number of larvae occupying 100 cm^2 during 3 summer months (July-September).	811	775	120	3944	319
Same, percentage with respect to the total number of larvae that had formed settlements in the corresponding year.	91%	83%	82%	98%	80%

out with special clarity that in 1957, when the rate of settlement reached exceptional magnitude for Gelendzhikskaya bukhta - more than 4000 larvae per 100 cm^2, the main portion of the larvae (98%) established settlements only during the three months of the hydrological summer.

Differences in the mean temperature of the hydrological summer between the lowest and highest rates of larval settlement equaled 2.2° C, which characterizes better the main regularity of variations in the intensity of settlement. On the other hand, a comparison of the number of settled larvae with the variation of water temperature in the warmest months of the year enables us to explain the extremely sharp quantitative differences in the reproduction of Teredo navalis L., which were observed by us in 1954-1958. On the basis of the data presented in Tables 3 and 4, we drafted brief characterizations of each month relative to the settlement of larvae.

Table 3

Number of Larvae of T. navalis L. Occupying Wood by Months (percentage with respect to the sum of larvae that had formed settlements during the entire warm season)

Year of observation	Months					Notes
	VII	VIII	IX	X	XI	
1954	14	39	38	7	2	Single larvae that had settled in June were not counted
1955	4	73	6	12	5	
1956	12	64	6	18	0	Single larvae that had settled in November were not counted
1957	3	23	72	2	0	
1958	14	57	10	19	0	
Mean for 5 years	9.4	53.2	26.4	11.6	1.4	

Of the five years of observations, single settlements of larvae in June were observed only in 1954. The average water temperature for June was, besides, unusually high, reaching 22° C for the second ten-day period and 24° C for the third ten-day period of the month. During all the other years we did not observe the settlement of larva in June.

It is evident that, with the temperature of about 20° C that was observed during the years, the number of larvae ready to form settlements was so insignificant that our small test panels did not record them.

July is the first of the warmest months in the summer season. In the years with the warmest summers (1954 and 1955) the mean water temperature of ten-day periods in the location of our observations equalled 25-27° C in July. Even in the years that differ with respect to temperature the settling of larval teredo begins, as a rule, with the first dates of July, but the process does not reach its maximum in this month: generally, July is characterised by a small number of settled larvae; on the average, less than 10% of the larvae that settle on wood in the season. Even in cases when the water temperature reaches the maximum for the entire warm season in July, it does not correspond to the maximum number of settled larvae. Obviously, the possibility of mass settlement in the following month is only readied in July.

Table 4

Mean Monthly Water Temperature during the Settlement Period of Larvae of T. navalis L. in 1954-1958

Year of observation	Months					
	VI	VII	VIII	IX	X	XI (I and II ten-day periods)
1954	22.0	26.3	25.3	22.1	19.3	17.0
1955	20.2	24.7	24.0	22.9	20.6	16.0
1956	19.9	22.5	24.0	20.6	16.6	11.7
1957	20.0	24.0	24.3	24.1	16.4	15.3
1958	21.0	22.9	24.4	20.5	17.0	15.5
Mean for 5 years	20.6	24.1	24.4	22.0	18.0	15.1

August is the decisive month in settlement by larval teredos. This month repeats the temperature of July, being usually somewhat warmer. In August one can observe the peak of settlement on wood when 1/2 to 3/4 of the larvae that establish settlements in the season occupy their places. Not infrequently, the peak of settlement is reached in one ten-day period, most frequently during the second or third ten-day periods.

In September the mean water temperature varies by years more pronouncedly than in any other summer month. Therefore the hydrological conditions in September may exercise a great influence on the total intensity of attack launched by teredos on wood in a given year.

Thus, the low temperatures of 20.5-20.6° C in September 1956 and 1958 were associated with insignificant settlement by larvae in the month. In 1957, on the contrary, the high mean temperature of 24.1° C corresponded to a great increase in the quantity of settling larvae, which made this year the most "productive" year for shipworms. In this case, the maximum peak was displaced to September and appeared to be no less outstanding than in the case of August.

In October the water temperature drops several degrees below the summer average. Nevertheless the settlement of larvae does not cease. The mean monthly temperature varies greatly from year to year. In a warm autumn it is about 20° C and, evidently, the planting and development of larvae in their pelagic stage still occurs in October. However, in years when the autumn cooling is rapid and the mean monthly temperature is about 16-17°, the settlement of larvae continues, of course, of the larvae that had been planted in September at a higher water temperature. Be that as it may, but on the basis of the relative portion of larvae that establish settlements in October, this month not only does not yield to July but even surpasses it to a degree. This pertains to warm years with a large concentration of larvae in water (1954, 1955, 1957), as well as to the years with a cool hydrological summer and a small number of larvae (1956, 1958).

As to November, the settlement by larvae were observed in the first /184
two ten-day periods and not every year, but only when the mean temperature of the ten-day period was about 16.5-17° C. The number of larvae that settle in November is insignificant in comparison to the total number of larvae that settle in the given season.

Turning to the characterization of the settlement seasons as a whole, it can be noted that in the most unfavorable years for Teredo navalis, only one month - August - is really warm, having a temperature of about 24° C. Such years were 1956 and 1958, which are characterized by a brief period of larval settlement — namely, four months. A temperature not high enough in July and August and cool water in September and October typify, for example, the year 1958; a prematurely cold hydrological autumn typifies the year 1956. However, one must take into consideration the fact that even at this temperature, which sharply lowers the number of settled larvae, they are, nevertheless, capable of committing serious damage to the hulls of vessels or even to the wharves.

The years, during which the number of larvae that were capable of establishing settlements on wood was considerable (1954 and 1955), were characterized by a long settlement period and high temperature in all the months of the period. The optimum temperature (24° C and more) in these years lasts for not one, but two months in succession — July and August. September has also been recorded as having relatively high temperatures, from 22° to almost 23° C. The temperature of October (about 20° C) corresponds to that of September, but the temperature of November corresponds to that of October in years with a cool summer. In 1954 the mean temperature of June was unusually high (22° C). In the third ten-day period of the month the water temperature rose to 24.3° C, as a result of which the settlement of larvae began earlier than usual.

The warm season of 1957, which excelled with a concentration of larvae, had typical temperature cc :itions. The temperature in this year remained at 24° C for three consecutive months — from July to September.

Otherwise, the season did not differ from the summer season of the cold years. In October the temperature dropped to 16.4°, but in June it did not exceed 20° C. The low temperature at the beginning of July (about 21° C) was, evidently, the reason for a late beginning of settlement by larvae — namely, in the second ten-day period of July. The settlement period in this year was short, as in the most unfavorable years for T. navalis L. Nevertheless, the attack launched by teredos on wood in 1957 was not only the most intense of the five observed years, but it was characterized by exceptional intensity for Gelendzhikskaya bukhta, where the activity of teredos is the smallest in comparison with all the other ports on the Caucasian coast. Although the high temperature lasted three months with several interruptions, the settlement of larvae was not uniform. A sharply pronounced maximum was confined to the very end of the period, when almost 3/4 of the total number of larvae for the year settled on wood.

As is seen, the number of larvae settling on wood in one or the other warm seasons, and, consequently, the quantity of the population for the year, does not exercise a decisive influence on the settlement of larvae in the following year. At least the intense settlement of larvae in 1955 was followed by an unusually weak settlement in 1956, and this extremely poor season with respect to the number of teredos was followed by a catastrophic attack on wood in 1957; the following season in 1958 was characterized again by a limited number of larvae. This underscores the decisive effect of temperature on the life, and mainly on the reproductive process, of T. navalis. This species, being so sensitive to the drop of temperature within the limits of its summer amplitude, should be considered a thermophilic species living in the waters of the temperate climate zone. Within the framework of our observations, a temperature of 24° and more appeared to be optimal for the reproduction of the species and the development of larvae ready to settle on wood. The temperature of 20-21° C appears to constitute the lower limit at which the development of larvae in their pelagic stage is possible and the occupation of wood can take place in the waters of the Black Sea. This concurs with conclusions derived by H. Kühl (1957) relative to the dependence of development of T. navalis larvae on the definite temperature level in the waters of the Mediterranean Sea. According to observations by Kühl, the species attacks wood only in years when the water temperature exceeds 20° C. In the five locations where the observations were conducted, the temperature was considerably lower than in the case of our observations conducted in Gelendzikskaya bukhta, which was associated with an extremely weak attack on wood by teredos. At Norderney (East Frisian Islands [Friesche Eilanden]), for example, where the water temperature slightly exceeded 20° C, at the end of the season only one to three burrows of teredos were found on 100 cm² of wood surface. In Wilhemshaven, where the water temperature sometimes reaches 24° C in July and August, but does not remain long at this level, the attack by teredos is considered intense when 10-20 burrows are made per 100 cm² of wood area. This is many times less than the number of teredos settling on wood in the most unfavorable year in Gelendzhikskaya bukhta.

Generally, in the North Sea T. navalis L. reacts to the lack of summer heat, in the same manner as in the Black Sea. The lower boundary of temperature, at which the development of the late stage of larvae and their settlement on wood occurs, and the optimum temperature for the reproduction of T. navalis, inhabiting the Black and the North Seas, coincide. The much smaller damage committed by the species along the coast of the Federal German Republic, as well as in the fjords of southern Norway, Sweden, and the Danish Straits, can be explained first by an insufficient level of temperature during the reproduction period. This explains the almost complete absence of T. navalis along the coast of Great Britain, including the waters of the British Channel.

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I. N. Soldatova

THE INFLUENCE OF WATER HAVING VARIOUS SALINITIES ON SOME OF THE PHYSIOLOGICAL PROCESSES OF THE BLACK SEA BIVALVE MOLLUSK *TEREDO PEDICELLATA* QUATREFAGES

Abstract

The survival, oxygen consumption, rate of growth, and formation of the larvae of the shipworm Teredo pedicellata Quatrf. of the Black Sea (salinity 17-18°/oo) were studied in the laboratory under conditions of varying salinity. It was found that within the range of 12-35°/oo the basic physiological processes of T. pedicellata are maintained on the same level as under the natural conditions of the Black Sea. This agrees well with the natural range of occurrence of T. pedicellata in nature.

Roch (1935) was the first one to describe the shipworm *T. pedicellata* of the Black Sea, one specimen of which was found in the Batumi area. In 1954 P. I. Ryabchikov (1957) found several specimens of the species in wooden blocks placed in the sea at Gelendshik. R. K. Kudinova-Pasternak (1958) reports the finding of a considerable quantity of *T. pedicellata* in Rybatskaya bukhta and Gelendshikskaya bukhta of the Black Sea. However, these authors do not give information on quantitative data on the distribution of *T. pedicellata* in the Black Sea.

When studying the ecology of *T. navalis* — the main enemy of wood in the Black Sea — I repeatedly found *T. pedicellata* in the infested wood. Some data on the quantitative relationship between both of the species were disclosed only by extracting all of the wood borers from the panels. It is seen from Table 1 that *T. pedicellata* is found only occasionally at places inhabited by *T. navalis*, and that the number of the former is many times smaller than that of the latter.

In connection with the invasion of marine borers into the Sea of Asov, investigations concerning their distribution were launched in the sea. *T. pedicellata* was first found in 1959 (Ryabchikov, Soldatova, and Yesakova, 1961); and, only in bukhta Chokrak, at village Mysovaya. The subsequent investigations of wood in the Sea of Asov (1960 and 1961) did not disclose the presence of *T. pedicellata*.

In connection with the possibility of further progression of *T. pedicellata*, it would be desirable to elucidate the salinity range of the Black Sea from the species. For this purpose, the effect of water of various salinities on the main physiological processes of *T. pedicellata* — notably on its survival, rate of oxygen consumption, and growth — was investigated.

The observations were conducted at a Black Sea experimental station of the Institute of Oceanology of the Academy of Science of the USSR (Rybatskaya bukhta) during 1957-1961. The test animals were obtained from the Novorossiysk and Gelendzhik areas, where the salinity was about 18°/oo.

The only study I know of which deals with the reaction of *T. pedicellata* to various salinities is a paper by Roch (1940). Roch obtained the test animals from Ravenna (Adriatic Sea), where the mean water salinity equals 37.32°/oo, the maximum being 38.40°/oo and the minimum being 34.77°/oo. The author studied the reaction of the animals to decreased salinities, whereby the water in aquariums containing the test animals was diluted gradually, 1-2°/oo a day. On the basis of observations on the intensity of wood boring and the reaction of siphons, the following sensitivity limits of *T. pedicellata* to the variation of salinity were established. The lowest limit for a normal /187
existence is 25°/oo; a decrease in boring and mobility of siphons occurs at 24-21°/oo; the lethal salinity (the lowest limit for a lasting preservation of life, the cessation of boring) is 20°/oo; the entrance holes are closed (the siphons are drawn in, state of complete immobility) at 16°/oo.

DATA AND METHOD

Observations on the survival of teredos were conducted during 1957-1958 and 1959-1961. They consisted of three series of tests. The first series began in October 1957 and ended in August 1958, whereby the age of test animals did not exceed 20 days. During 1959-1960 (second series) and 1960-1961 (third series) the observations were conducted from August to September, whereby the age of test animals did not exceed 12-15 days at the beginning of the tests.

In the first two series, the number of test animals was not counted: only after the end of observations were all the mollusks extracted from wooden panels that had been kept in water with various salinities, and the number of live *T. pedicellata* was counted. The observations

Table 1

QUANTITATIVE RELATIONSHIP BETWEEN T. NAVALIS AND T. PEDICELLATA IN SOME OF THE SECTIONS OF THE BLACK AND AZOV SEAS

Place of observation	Date of observation	Number of individuals of both species	Number of T. pedicellata	
			ind.	°/o
Black Sea				
1957				
Novorossiysk. . . .	16 Aug-29 Aug	202	39	18.3
Novorossiysk. . . .	15 Sep-10 Oct	358	79	22.0
1958				
Gelendzhik.	1 Sep- 1 Nov	136	24	17.6
Novorossiysk. . . .	3 Jul- 3 Oct	168	—	—
Gelendzhik.	1 Oct-30 Oct	184	12	6.5
Novorossiysk. . . .	3 Oct-28 Oct	144	17	11.8
1959				
Gelendzhik.	3 Jul- 3 Aug	138	—	—
Gelendzhik.	15 Aug- 1 Sep	1301	155	12.0
1960				
Gelendzhik.	19 Aug- 1 Sep	810	168	21.0
Sea of Azov				
1959				
Mysovaya.	1 Jul-17 Sep	184	20	10.3

of the third series were conducted as follows: each of the panels were examined with the aid of binoculars and the openings of burrows with live teredos were encircled by a pencil, after which the panels were submerged into water with the desired salinity. About 80-90 animals were placed in each concentration of salinity. The animals belonged to two species — T. navalis and T. pedicellata; it was impossible to make a distinction between them at such a young age (the age of test animals did not exceed 12 days at the beginning of the test) without the extraction of the animals from the wooden panels. Only after the end of the tests, when all the live teredos had been extracted from the wood and the burrows of the dead animals had been opened, was the species composition of the animals determined on the basis of the form of the pallets - i.e. the calcareous lamina that lock the burrows. Thus, the number of surviving and dead animals, out of the original total number of test animals, was determined after they had been kept for a year in water with a given salinity.

The first series of tests was conducted in water with the following salinities: 10, 12, 14, 18 (the salinity of Black Sea water), 26, 28, and 30°/oo. The second and third series of tests were conducted in water with salinities 8, 32, and 35°/oo in addition to the above mentioned salinities.

The rate of oxygen consumption by T. pedicellata was conducted in the same way as in the case of T. navalis (Soldatova, 1961a, b). Therefore the method will be briefly discussed. The rate of oxygen consumption was determined in animals inhabiting the core of the wood. The tests were conducted in water with decreased and increased salinities (10, 12, 30, and 35°/oo). The test animals were kept in Black Sea water, the salinity of which fluctuated from 17.8 to 17.4°/oo. The quantity of dissolved oxygen was determined by the Winkler method.

Altogether, two series of tests were set up, as a result of which the respiration of 26 individuals was determined; each of the individuals was placed in a separate respiratory container [1]. During the first four to five days the quantity of consumed oxygen in the Black Sea water was determined in all the test animals; afterwards, six of the animals were left in the Black Sea water and were used for verification of results, while the remaining animals were transferred to water with salinities of 10, 12, 30, and 35°/oo with five individuals in each type of water, where the observations continued for 8 to 11 days.

The growth rate was determined by the length of burrows made by the mollusks in the wood. It was demonstrated before, in connection with T. navalis, that the length of burrows serves as a good exponent of growth rate (Soldatova, 1961b).

[1]Because both of the series of tests were conducted at similar temperatures (23.8-21.1° C), the results will be discussed together.

In order to determine the entire cycle of development of gonads and the subsequent formation of larvae in the gill cavity of the maternal organism, when the mollusks are kept in water with various salinities, only the last stage of the process — the releasing of a free-swimming larva — was investigated. For this purpose, the young sexually immature animals not exceeding 20 days of age were placed in aquariums with salinities ranging from 8-35°/₀₀. Three series of tests were conducted during 1957-1961. The wooden panels infested with teredos were put into water with various salinities by the end of summer or the beginning of autumn, keeping them in the given conditions for one year.

Because the panels were simultaneously infested with two species of shipworms, whose larvae could not be identified, I proceeded as follows. By the end of summer, when the animals reached large sizes and it was possible to identify the species without extracting them from their burrows, all the T. navalis individuals were killed, leaving only T. pedicellata.

Beginning with July, the water samples of aquariums with test animals were examined with the aid of binoculars each three to four days. In the sea water, that is sent to laboratories, one can seldom find moving larvae, but in the cases, when they were encountered, their number never exceeded 1 in 50 cm^3 of water. However, if one finds a great number of floating larvae — from 10-20 to several hundreds in 50 cm^3 — there is no doubt that the spawning is taking place in the animals that are kept in the aquarium.

In the tests designed for studying the rate of oxygen consumption, survival, and formation of larvae the animals were transferred from Black Sea water to a water having the salinity of 14 and 28°/₀₀. After each two day period, the animals were transferred to water whose salinity was 2°/₀₀ higher than in the preceding type of water. A direct transfer of mollusks into water having the salinities of 14 and 28°/₀₀ appeared to be possible, because such a variation of salinity did not cause noticeable disturbances in such a sensitive phenomenon of organism as respiration. /189

The water with an increased salinity was obtained by the evaporation of sea water and dilution of the concentrated Black Sea water. The water with a decreased salinity was obtained by the dilution of Black Sea water with a pure water.

The test animals were fed by a culture of flagellate algae such as Rhodomonas baltica, Chlamydamous minima, and Exuviella sp.

The mollusks, designated for the determination of the rate of oxygen consumption, were kept in glass containers with a capacity of 4 liters; the water was replaced once a day. The mollusks designated for the determination of survival rate and formation of larvae were kept in aquariums (6-8 liters) with running water having the needed salinity.

RESULTS OF OBSERVATIONS

Survival. As was already mentioned, the determination of salinity range in which the Black Sea individuals of T. pedicellata could exist was carried out by three series of tests, but only the results of the third series made it possible to obtain quantitative data. The discussion of the data will begin with this series. As seen from Table 2, a dilution to 14°/oo and salinification to 35°/oo did not cause a noticeable death rate of the test animals.

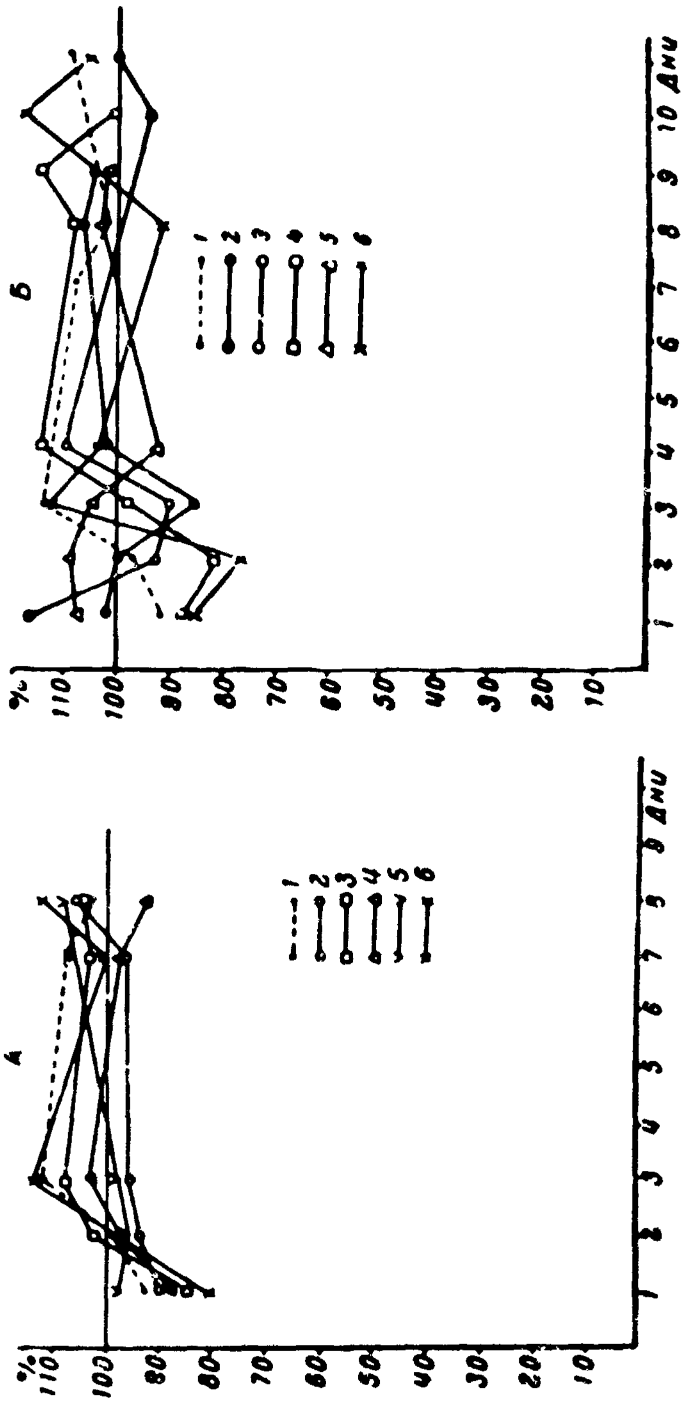
Table 2

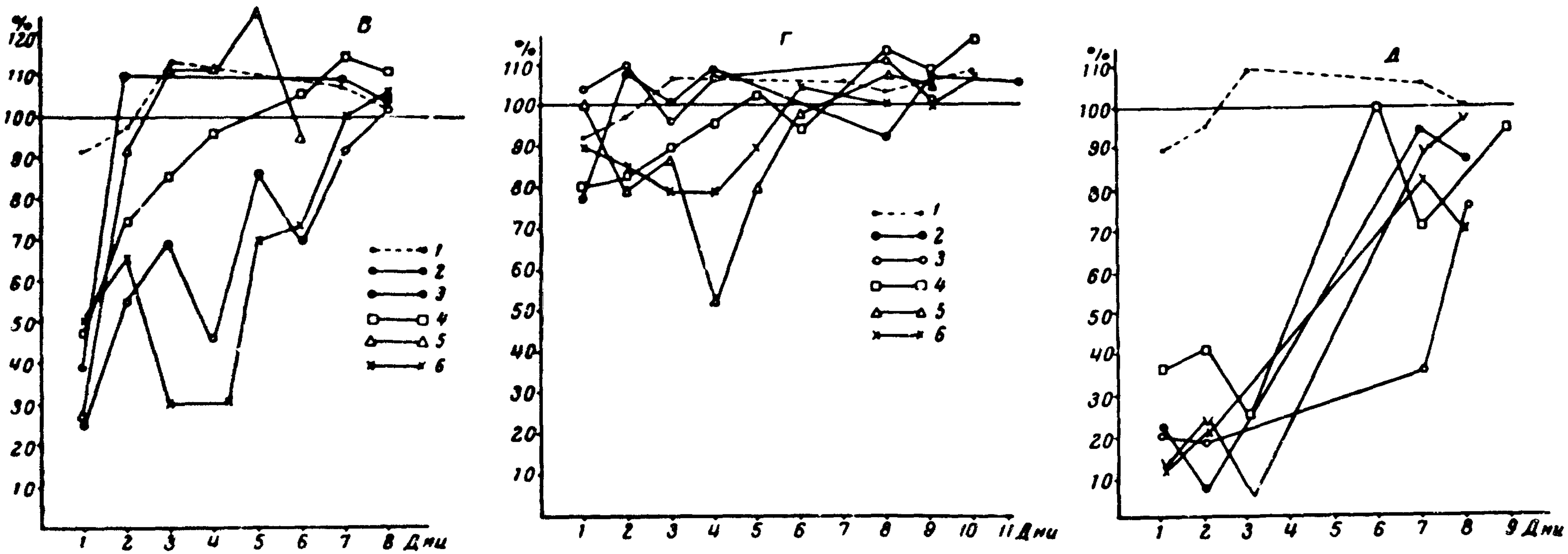
Survival of T. pedicellata in Water with Various Salinities (observations conducted in 1960-1961)

Number of animals	Salinity of water, °/oo								
	8	10	12	14	18 (sample test)	26	28	32	35
At the beginning of test. . .	19	16	28	23	34	18	20	20	38
At the end of test.	0	4	16	18	28	16	18	16	32
Percentage of survivors . . .	0	25	59	78	82	89	90	80	84

In water having a salinity of 12°/oo the number of deaths was 23°/o higher than in the Black Sea water, but at 10°/oo the number reached 57°/o. Lastly, in water whose salinity was 8°/oo all the animals perished.

The two other series of tests gave the following results. In the first series the mollusks were kept in water having salinities of 10, 12, 14, 18, 26, 28, and 30°/oo; live teredos were found in each type of water at the end of the test. In the third series of tests the observations were conducted in water having salinities of 8, 32, and 35°/oo in addition to the above mentioned salinities; also here one could observe live mollusks at the end of the tests.





Rate of oxygen consumption by <u>T. pedicellata</u> in water having various concentrations of salinity.

1 — sample test; 2 to 6 — various concentrations of salinity: A — 14; Б — 30; B — 12; Г — 35; Д — 10.

<u>Key</u>. Horizontal axis: days.

Thus, the data of all the three series of tests agree well among themselves. The data of these tests attest to the fact that T. pedicellata of the Black Sea can live for a lengthy time period (about a year) in water with salinities varying from 8 to 35°/oo. However, the number of individuals surviving in the conditions varies. The limits of salinity, within which the number of survivors is about the same as in the sample test, are 14-35°/oo. A dilution exceeding 14°/oo leads to a higher death rate, whereby in water whose salinity is 8°/oo the main mass of the animals perishes.

The rate of oxygen consumption. The figure shows the oxygen consumption of T. pedicellata during 8-11 days at a given salinity. The abscissa indicates the number of test days, but the ordinate shows the use of oxygen in percentages of normal consumption.

If the salinity of water is either 14 or 30°/oo (see the Figure, A, Б), in part of the animals the oxygen consumption decreases slightly during one to three days - never exceeding 23°/o of normal consumption. If the animals were kept two to four days in the same conditions, the rate of oxygen consumption in all of the test animals became normal for the Black Sea water until the end of the test. In some individuals, such a variation of salinity did not exercise any influence on the rate of oxygen consumption.

When the animals were placed in water having the salinity of 12°/oo (see Figure, B), the use of oxygen decreases sharply to 75°/o of the normal rate in the first day of the test. The resumption of normal rate occurs from the third to the seventh day if the animals are kept in the same conditions. An increase in salinity to 35°/oo (see Figure, Г) creates a reaction similar to, yet slightly weaker than, the one described above. The greatest deviation from the normal level equaled 48°/o, but in one animal put in a water with such concentration of salinity no change in the speed of oxygen consumption was noted. The resumption of the normal rate of oxygen consumption takes place during the second to the sixth day, whereby the respiration becomes normal in all of the test animals.

The keeping of animals in water whose salinity is 10°/oo (see Figure, Д) leads to the most profound and lasting disturbances in respiration. During the first day the use of oxygen decreases to the maximum value - 88°/o - if the teredos are kept in water with such a low salinity. The resumption of normal respiration does not take place in all of the test animals.

Growth rate. The reaction of the animals to dilution was rather similar in all of the three series. A decrease in salinity to 14‰ either did not cause a decrease in the average size of the animals, or the animals kept in water having the salinity of 14‰ reached a larger size than those kept in the normal sample water (Table 3).

The mean size of animals kept in water having the salinity of 12‰ reached, in two series (second and third), the size of animals living in the Black Sea water; in the first series of tests the mean size of animals was 21% below the normal size. The keeping of teredos in water having a salinity of 10‰ always exercised unfavorable influence on their growth. The mean size of animals taken from water having a salinity of 10‰ was considerably smaller than the mean size of animals living in normal conditions - namely, in the first series of tests the difference was 38%, but in the second and third series it was 32 and 63%, respectively. In a water having the salinity of 8‰, only three live mollusks were found during the entire test period; their size was 69% below the normal size.

An increase in salinity to 30‰ in the first series of tests and to 35‰ in the third series of tests did not affect appreciably the size of the animals: the deviations, observed in the tests, never exceeded 10% of the normal value and therefore the effect was hardly noticeable. In the second series of tests the animals reached incomparably greater size than those living in normal conditions, namely: 26‰ corresponded to 52%, 28‰ to 26%, 30‰ to 34%, and 32‰ to 26%. In water with a salinity of 35‰ in the third series of tests the size of the animals was almost equal to the size of animals living in normal conditions. /193

In water with a salinity ranging from 35 to 12‰, the development of sexual products, fertilization, and development of larvae in the maternal gill cavity occur normally. This is confirmed by a large number of floating larvae, found during the summer in aquariums where the salinity of water ranges from 35 to 12‰. The size of larvae, kept in normal and experimental conditions, varies from 79 to 87 μ.

DISCUSSION OF RESULTS

The dissimilar reaction of individuals of the same population to water with various salinity concentrations is well known. Experimentally, however, it has been confirmed only recently (Kinne, 1956; Turpayeva, 1961; Turpayeva and Simkina, 1961; Soldatova, 1961a). The dissimilar

Table 3

Mean Size of T. pedicellata in Water with Various Salinities

Salinity, °/oo	I Series			II Series			III Series		
	number of ind	mean size		number of ind	mean size		number of ind	mean size	
		mm	°/o of normal value		mm	°/o of normal value		mm	°/o of normal value
8	—	—	—	3	14	37	All perished		
10	12	18	62	25	26	68	18	20	37
12	12	23	79	32	36	95	32	52	96
14	48	29	100	18	49	128	20	56	103
18 (normal cond)	29	29	100	26	38	100	36	54	100
26	46	28	97	24	58	152	20	55	98
28	10	27	94	47	48	126	24	59	109
30	41	29	100	22	51	134	—	—	—
32	—	—	—	18	48	126	26	51	95
35	—	—	—	—	—	—	40	49	90

character of populations has been manifest in the tests conducted with the Black Sea T. pedicellata. This is especially noticeable with respect to the material pertaining to survival. Teredo is capable of living within a salinity range of 8 to 35°/oo (tests with salinities exceeding 35°/oo were not conducted). The number of mollusks capable of living within the given salinity range varies. Only salinity ranging from 14 to 35°/oo, which does not increase the natural death rate of mollusks, can be considered as favorable. Dilution below 14°/oo causes a progressively increasing death rate. Thus, at 12°/oo the number of dead animals exceeded by 23°/o the number of dead animals in natural conditions, while at 10°/oo the difference was 57°/o. The salinity of 8°/oo appeared to be lethal for the main mass of animals. The dissimilarity is also manifest in tests determining the rate of oxygen consumption. Dilution to 12°/oo and below and an increase in salinity to 35°/oo lead to a considerable change in the rate of oxygen consumption, whereby the rate varies from one individual to the other (see Figure, B, Д).

Salinity variation to a definite limit is almost without effect on the rate of oxygen consumption by the animals. A further deviation from these conditions leads to noticeable variations in the rate of oxygen consumption. Thus, the placement of animals in water having the salinity of 12°/oo creates a sharp decrease in the rate of oxygen consumption during the first day of the test; but later — during the second to the eighth day period — the rate is again normalised. An analogous phenomenon — a decrease in the rate of oxygen consumption with a subsequent restoration of it — is also observed when the animals are placed in water having a salinity of 35°/oo, although in this case the variation in the rate of oxygen consumption is less pronounced and of shorter duration than at the salinity of 12°/oo. At 10°/oo a decreased use of oxygen in part of the animals is preserved during the entire test period (8 days) and, consequently, the adaptation of the animals to these conditions is either very much aggravated, or generally impossible. Indeed, the examination of data on the growth of teredos demonstrates undoubtedly that only in water with salinities ranging from 12 to 35°/oo is the mean size of animals, as a rule, the same or somewhat greater than in animals living in Black Sea water. In water whose salinity was 10°/oo the animals never reached the size of the individuals kept in Black Sea water. The smallest deviation from the standard equalled 32°/o, the greatest was 63°/o. The release of larvae was never observed at this salinity, while at salinities ranging from 12 to 35°/oo the spawning was repeatedly observed. Thus, when the salinity range is limited to 12 and 35°/oo the animals preserve their basic physiological processes at the same level, as is observed in natural conditions of the Black Sea. Almost the entire salinity range from 12 to 35°/oo was characterised by animals leading an almost normal life. The only exception is a salinity of 12°/oo at which the number of perishing animals exceeded slightly the corresponding number of animals inhabiting water the salinity of which is normal to them.

In the process of individual development in the Black Sea areas where T. pedicellata was found - namely, in the Novorossiysk and Gelendzhik areas - the species is confronted only with small fluctuations in salinity, from 18.2 to 16.5°/oo. In the Sea of Azov the representatives of the species have been found only in the most saline areas where the salinity ranged from 12 to 13°/oo. Therefore, the fact that the Black Sea mollusk can live in waters with oceanic salinity is indicative of the marine origin of the species.

T. pedicellata was found along the coasts of Western Europe, Azores, Madeira, Canaries, West Africa as far as Angola, east coast of North America, Australia, in the Mediterranean and Adriatic Seas. However, the information on the salinity of waters in which T. pedicellata has been found exists only for the Mediterranean and Adriatic Seas, as well as for the Miami area.

According to data by Roch (1940), this species is widely distributed in all of the large harbors of the Mediterranean Sea, whereby the salinity in the latter sea varies from 36.3 to 39.6°/oo. In the Adriatic Sea the species is as widely distributed as in the Mediterranean Sea, and it propagates here not only at oceanic salinities but also in the northwestern corner of the sea, where, due to the fluvial water discharged by the Alpine rivers, a considerable dilution is observed; T. pedicellata has been found even in the most diluted coastal water at Marina di Ravenna, where the mean salinity of the coastal water equals 24.4°/oo, the maximum being 36.04°/oo and the minimum 5.32°/oo.

In the Miami area, T. pedicellata was also found in places with oceanic salinity, as well as in considerably diluted areas (Greenfield, 1952) (Table 4).

Table 4

Salinity of Water and Intensity of Settlement Establishments in the Miami Area (Miami Harbor and Rivers) (after Greenfield, 1952)

Exposed portion of harbor *			Part of harbor subjected to intense influence of river discharge **		
Month	Salinity, °/oo		Month	Salinity, °/oo	
	surface	bottom		surface	bottom
Mar	36.5	36.5	Mar	24.8	35.3
Apr	37.3	36.9	Apr	26.8	34.3
May	38.0	38.2	May	34.0	37.2
Jun	39.1	39.0	Jun	28.4	31.8
Jul	34.0	34.6	Jul	20.8	22.9
Aug	34.0	34.8	Aug	13.0	33.2
Sep	36.4	37.2	Sep	22.0	25.2
Oct	33.8	35.2	Oct	20.1	28.4
Nov	34.2	34.8	Nov	19.5	26.5
Dec	34.6	34.6	Dec	10.3	26.6
Jan	36.2	36.2	Jan	18.0	28.2

*Mean number of larvae occupying 100 cm^2 in a month equals 59.

**Mean number of larvae occupying 100 cm^2 in a month equals 46.

As seen from Table 4, the total number of larvae settling on wood in two places of the gulf with different salinities is very similar. Further, the observations on the settlement of larvae at various depth levels demonstrated that in both of the places the process occurred at all the depths. The settlement of larvae in the Miami area takes place throughout the year, and, consequently, the smallest value of salinity that does not obstruct the settlement of T. pedicellata is 10.3-13°/oo (the mean salinity for December and August).

The summer limit of salinity of 20°/oo, which was established by Roch (1940) for T. pedicellata, is much too high because the T. pedicellata population that inhabits the Miami area at salinities of 10-13°/oo would be able to exist at salinities of 12-18°/oo in the Black and Azov Seas.

The above-mentioned data on the distribution of T. pedicellata in natural conditions attest to the fact that the species is capable of becoming established at salinities ranging from 39 to 10.3—13°/oo. The salinity limits for the existence of T. pedicellata in natural conditions, which were established by my tests (12-35°/oo), appeared to be similar. Such results were also obtained for T. navalis (Soldatova, 1961a), Mercierella enigmatica (Turpayeva, 1961), and Stiliger bellulus (Turpayeva, in this collection of papers).

The results confirm the opinion that the degree of stability of individuals of a species with respect to salinity is determined not only by living conditions of a given population, but also by the entire salinity range of the existence of a species in natural conditions.

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REACTION OF THE AZOV NUDIBRANCHIATE MOLLUSK STILIGER BELLULUS (D'ORBIGNY) TO THE SALINITY OF WATER

Abstract

The greatest tolerance to changes of salinity was observed in adult Stiliger bellulus; they survived within a salinity range of 3-55°/₀₀; least resistant were larvae during the process of metamorphosis, the salinity range being 3-40°/₀₀. Changes of salinity caused a decrease of fertility and heavy losses of larvae and young. They exerted also a marked effect on the growth rate of young mollusks and affected the general pattern of growth. Alterations of the investigated processes were especially pronounced in the generation P. In F_1 and F_2 generations the processes were smoothed out, frequently almost to their normal level, by adaptation and by selection and subsequent reproduction of the most resistant individuals.

The small nudibranchiate mollusk Stiliger bellulus (d'Orbigny) (fam. Opistobranchia), living on the stolons of hydroids, plays a significant role in the biocoenosis of fouling on the intake structures and pipe lines of the metallurgical plant situated on the shores of the Sea of Asov. The population reaches its peak in the second half of the summer; thus, in July 1961 more than 7000 ind. of nudibranchiate mollusks 4-5 mm long and weighing 100 g were found on the colonies of hydroids. The species feeds on the bodies of hydroids, gnawing a hole in the new segments of stolons and in the developing buds. The nudibranchiate mollusk feeds, evidently, also on mature hydranths. The tests conducted by me demonstrated that one mollusk 5 mm in size can destroy in a day as many as 100 mature hydranths.

The geographical area inhabited by S. bellulus is wide. The species is known in areas with oceanic concentration of salinity in the Atlantic Ocean, along the shores of Great Britain, and in the North and Mediterranean Seas. Recently it has been found in brackish waters — in the Black Sea, along the shores of Bulgaria (V"lkanov, 1955), and in Sevastopol'skaya bukhta (Chukhchin, 1960). Up to the present time the species has not been found in the Sea of Asov. It is not mentioned in the detailed catalog compiled by F. D. Mordukhay-Boltovskiy (1960). In August 1960 I succeeded in finding the species[1] in marine fouling in the Zhdanov areas, as well as in Kerchenskiy proliv along the coast of Kamysh-Burunskiy poluostrov.

The appearance of S. bellulus in Sevastopol'skaya bukhta, the fauna of which has been very thoroughly investigated, and its occurrence in the Sea of Azov make us assume that the species has recently penetrated our brackish southern seas. In this connection it was interesting to elucidate the reaction of the Azov S. bellulus to various concentrations of salinity, the more so, because up to the present time detailed investigations of nudibranchiate mollusks have not been conducted.

DATA AND METHOD OF STUDY

Young individuals of the species 2-2.5 mm long, which had been obtained from the stolons of hydroids, were used as material for tests. The animals were placed in small cups with round bottoms, two in each, (the diameter being 4-5 cm, height 3-4 cm) containing water with the given salinity concentration. Young segments of hydroids with hydranths and gonophores served as food. The water and food was changed each day. /198
The broods made during the day were removed together with the stolons of hydroids. The spawns were removed from the stolons of hydroids and the walls of the containers[2], and placed in separate burets filled with water having the same salinity as in the cups where the mollusks were kept. The number of eggs in each spawn was counted. Either veligers, or young mollusks, undergoing a metamorphosis within the spawn appeared in a certain time. No regularity was observed in the variation of quantitative relationship between the veligers emerging from the spawns, and the young mollusks that had undergone the metamorphosis in water the salinities of which varied. The number of young appearing from spawns was counted daily. Also the quantity of undeveloped eggs was counted.

In order to observe the survival and growth of young mollusks, 15 to 20 individuals not exceeding the age of 24 hours were put into cups with water having the required salinity; each day their number was

[1]V. D. Chukhchin determined S. bellulus.

[2]Sometimes the mollusks deposited their broods even on the surface film of water.

counted and length measured. The general length of body was assumed to be the indicator of growth. This indicator cannot be considered as very useful because the body of the mollusk is very elastic, and its length often changes considerably. Therefore, if possible, the length of a completely stretched animal was measured. The great number of measurements (usually about 100) assured a small error which could be neglected.

A mathematical processing of the materials demonstrated that the growth of Stiliger bellulus is subjected to the equation of parabola $L = mt^k$, where L denotes the general length of organism, m is the size of organism at the end of the first time unit after the beginning of growth, t is the time, and k is the exponent characterising the intensity of growth. The magnitude k varied considerably with various periods of life. In this connection, with a view to characterising the intensity of growth of small individuals of the species, a method suggested by I. I. Shmal'gausen (1935) for studying the regularities of growth of vertebrate animals was used by us. Underscoring the extraordinary importance of the magnitude[1], which is considered by him as a factor of growth intensity, Shmal'gausen recommends that it be computed by the formula

$$k = \frac{\lg l_2 - \lg l_1}{\lg t_2 - \lg t_1},$$

where t_1 and t_2 denote the age of animals at two consecutive counts, whereas l_1 and l_2 denote the size of the animals at the same counts. This formula is very convenient because it gives direct comparable values for various organisms, which are entirely independent of both the selected scales of the magnitudes and the time units.

The tests with Stiliger bellulus were conducted in water having the salinity of 1-55°/oo. The sample animals were kept in a water having the salinity of 8°/oo, and taken from the natural habitat of the mollusks. Because of a short life span of the species (the mollusks live about one month), the transfer of the animals to another concentration of salinity had to be made rather frequently, and their keeping

[1] I. I. Shmal'gausen calls the magnitude k a "growth constant". Because the "constant" is assumed to denote a constant magnitude, but in our case, it is possible that in connection with a small life span of the animal, k often varies, and therefore we shall call it a "coefficient".

in water with intermediate salinities was short. Thus, when the salinity was decreased, the animals were kept for a day at $5^{\circ}/_{oo}$, two days at $3^{\circ}/_{oo}$, and only then were they transfrerred to a water having the salinity of $1^{\circ}/_{oo}$. When the salinity was increased, the mollusks were transferred from water having the salinity of $8^{\circ}/_{oo}$ to water having the salinity of $18^{\circ}/_{oo}$ and later, with the intervals of two days, to increased salinities (30, 35, and $40^{\circ}/_{oo}$). In addition, young mollusks born and developed at $35^{\circ}/_{oo}$ were chosen for tests in water with salinities of 40, 45, and $50^{\circ}/_{oo}$. The salinity concentration was obtained by the dilution of concentrated Black Sea water ($90^{\circ}/_{oo}$) with the aid of the Asov water having the salinity of $8^{\circ}/_{oo}$.

Observations were conducted on individuals of various generations and therefore symbols are used in this study. The parental generation, taken for the tests from their natural habitat, is denoted by a Latin letter P; their offsprings in the test are denoted by F_1; the following generation is denoted by F_2. In this connection, also the spawns are denoted by symbols: the spawns of parents are denoted as F_1 spawns, and the spawns of the generation F_1 are denoted as F_2 spawns.

The work was carried out in June—August of 1961. The water temperature in the tests was maintained at 23-26°.

Observations on survival and growth were conducted for a period of 15 to 20 days. The total length of tests designed for studying the reaction of S. bellulus to water with various salinity concentrations was one to two months.

RESULTS OF OBSERVATIONS

Reaction of individuals of the parental generation. When transferring the young individuals of the parental generation from water taken from their habitat to water with a different salinity, the reaction was always rapid: the mollusks shrank, ceased to crawl over the stolons of hydroids and often even left the stolons, falling to the bottom of the cup. After a considerable period of time, not exceeding a day, part of the mollusks recovered their functions, began to feed, and spawn, whereas the other part perished; the greater the discontinuity of salinity concentration, the smaller was the number of animals that survived the change.

The lowering of salinity from 8 to 5°/oo was rather well endured by the mollusks, although in the first hours of transfer, their bodies inflated considerably, evidently, from the water entering the tissues. When the mollusks were transferred from a concentration of 8°/oo to that of 3°/oo, they appeared to be very depressed and the main portion of the animals perished. A gradual decrease of salinity (from 8 to 5°/oo and then in two days to 3°/oo) did not create a great death rate. Two or three days spent in water having the salinity of 3 /oo was sufficient for the restoration of their normal life: the mollusks were active; they ate normally and spawned. A still greater decrease of salinity to 1°/oo, even by a gradual change of water, caused a deep depression which could not be overcome by the mollusks. All of the test animals perished in four to five days.

<u>Adaptation to conditions of increased salinity</u>. A change of salinity from 8 to 18°/oo did not create any changes in the behavior of mollusks. With a variation of salinity from 8°/oo to 24°/oo a temporary depression occurred, which ceased without consequences in 12-18 hours. If the salinity was changed from 8°/oo to 30°/oo the depression was more pronounced, whereby about 2/3 of the animals perished. A direct transfer from 8°/oo to 35°/oo was endured only by a few individuals. With a gradual change of salinity from 8°/oo to 40°/oo, the depression was mild; the animals ate and spawned, but the quantity of eggs de- /200
creased in comparison to the quantity laid by the mollusks of the same size at 35°/oo. A further gradual increase of salinity to 45°/oo led to a considerable depression in the animals. The animals became very lazy, they were hardly holding themselves on the stolons of hydroids and perished gradually in seven to eight days, although in the first five to six days they deposited daily a small amount of eggs. A variation of salinity to 50°/oo was not endured by the mollusks, and they perished in two to three days.

The F_2 mollusks born and raised in water having the salinity of 35°/oo endured high salinity concentrations considerably easier. The mollusks of this generation, when transferred to 45°/oo, lived more than two weeks without a considerable rate of death. If transplanted from 35°/oo to 50°/oo, the F_2 mollusks survived and deposited single spawns with a limited number of eggs in the first days. The F_2 mollusks transplanted from 35°/oo to 55°/oo lived ten days, after which the test was discontinued. However, in such water the spawns were not deposited.

Fertility. As demonstrated by observations at salinities 3-45°/oo, the fertility of S. bellulus increases with length (Table 1). Small individuals, approximately 2.5 mm long, deposit on the average two spawns with two to three eggs. Large animals (exceeding 5 mm) deposit on the average about 10 spawns containing 12-18 eggs; sometimes the number of eggs in large individuals reaches 35-40 per spawn. The greatest fertility of large mollusks is observed at 8°/oo. With an increase in salinity the fertility of the animals somewhat decreased by 25°/o at 30°/oo, and by 35°/o at 35°/oo. In smaller individuals (4.0-4.5 mm long) the fertility was about the same at salinities ranging from 8 to 35°/oo. With a decrease or increase of salinity, the fertility of mollusks decreased considerably. In still smaller animals, a more or less similar fertility was observed at salinities ranging from 5 to 35°/oo, and a decrease was observed only at 3 and 40°/oo. The smallest animals deposited approximately the same number of eggs in a wider salinity range in comparison to the large animals (from 3 to 35°/oo).

With a considerable increase in the salinity of water the minimal size of animals capable of depositing eggs increases considerably. The first spawns are always deposited by mollusks 2.2-2.3 mm long in the entire range of salinity (3 to 35°/oo). With a salinity of 40°/oo the first spawns were deposited by mollusks 2.8 mm long, but with a salinity of 45°/oo the corresponding size was 3.2-3.3 mm.

The development of larvae occurs at a rather rapid rate. In a day after the settlement, the mobile trochophores can be clearly seen in the spawns, but three to four days later young mollusks leave the spawns. Viable F_1 larvae were produced within a wide salinity range: from 3 to 40°/oo. An F_2 generation was produced by mollusks (F_1) developed of larvae at salinities ranging from 3 to 35°/oo. On the basis of Table 2, one can assume that at salinities ranging from 5 to 35°/oo, the number of larvae was more or less constant. A considerable decrease in the number of F_1 larvae was observed in water having the salinity of 3°/oo: 73°/o of the larvae perished in spawns at various stages of development, mainly at the trochophore stage. With the salinity of 35°/oo, the same number of larvae developed from F_1 and F_2 spawns.

With the salinity of 40°/oo the number of developing F_1 larvae was small (the parents had been gradually transferred from water of 8°/oo to water of 40°/oo), yet the larvae did not leave their spawns but perished, mainly at the veliger stage. In water of 45°/oo the F_1 larvae perished at earlier stages of development (trochophore). At salinities of 40°/oo one could obtain viable larvae of mollusks of the F_2 generation, which had been raised at 35°/oo and transferred to water 40°/oo; the number of F_3 larvae that left the cells was considerable. In water having the salinity of 45°/oo all the larvae of the generation perished in the spawn, but some of them developed for seven to eight days and had a clearly pronounced germ.

Table 1

Diurnal Fertility (number of spawns and eggs) of S. bellulus of Various Sizes in Water having Various Salinities*

Size of mollusks, mm	Salinity, °/oo													
	3		5		8 (control sample)		30		35		40		45	
	spawns	eggs	spawns	eggs	spawns	eggs	spawns	eggs	spawns	eggs	spawns	eggs	spawns	eggs
2.5	2	4	2	5	2	4	3	6	2	4	No spawns		No spawns	
3.0	2	14	3	39	4	39	6	41	6	48	4	14	"	
4.0—4.5	3	22	6	91	7	137	9	158	8	153	5	59	3	31
5.0—5.5	—	—	—	—	11	227	11	171	8	148	7	117	—	—

*The parental generation of mollusks was kept in water with salinity ranging from 3 to 35°/oo; the mollusks bred at 35°/oo were kept in water having the salinities of 40 and 45°/oo.

The period of larval development in water having various salinities was dissimiliar (Fig. 1). The main part of larvae of the control sample (80°/o) developed within four days. With an increase of salinity to 18°/oo the period of development of F_1 larvae did not change. With a further variation of salinity, a considerable retardation in the development of larvae in spawns was observed.

Table 2

Number of *S. bellulus* Larvae Leaving the Spawns in Water with Various Salinities

(°/₀ of the total number of eggs)*

Spawn	Salinity, °/oo							
	3	5	8 (control sample)	18	30	35	40	45
F_1	27	87	99	89	89	89	0	0
F_2						90		
F_3							80	0

*Parental generation of spawns deposited at 40 and 45°/oo; F_2 mollusks developed at 35°/oo.

At 30 and 35°/oo about 70°/o of F_1 larvae developed in five days, and only 15-18°/o of larvae left the spawns in four days. At 40°/oo, the greater portion of F_1 larvae (86°/o) developed in six days. At 5°/oo the greater portion of F_1 larvae (about 65°/o) developed in five days, but 30°/o in six days. At 3°/oo, the greater portion of F_1 larvae (75°/o) developed in six days and only 25°/o needed five days to leave the spawn.

In water with salinities of 35 and 40°/oo the rate of development of larvae in spawns deposited in various periods of the life of the parents, as well as in spawns of various generations, was different. More than 80°/o of F_1 larvae, which were developed from eggs deposited on the second day after their parents had been kept at the salinity of 35°/oo (Fig. 2, A), developed within seven days; the same number of larvae developed within six days from the spawns deposited on the 8th and 9th days in the given salinity, but 90°/o of the larvae developed within five days from spawns deposited on the 14th and 15th days in the given salinity. At 35°/oo the F_2 larvae also developed within five days. The same rate of development was observed in F_1 and F_2 larvae at $30°/_{oo}$. Thirty percent of the larvae that developed from spawns deposited by parents on the 2nd and 3rd days after having been kept at $40°/_{oo}$ (Fig. 2, б) developed in six days, while $65°/_o$ of them developed in seven days; the main mass of larvae which developed from spawns that had been deposited on the 5th to 7th days at a given salinity developed in six days.

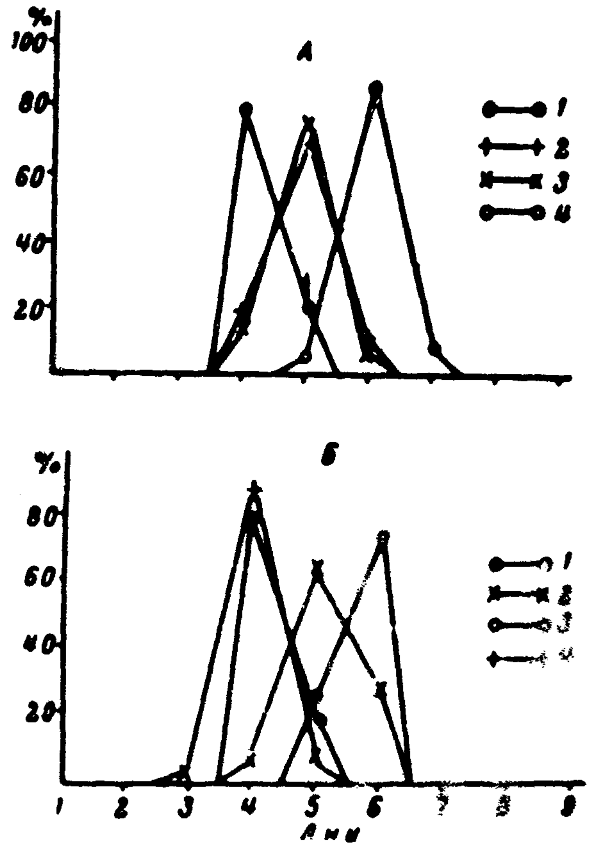

Fig. 1. Mean number of S. bellulus larvae leaving the spawns by days (in °/° of the total number of larvae that had left spawns).

A — tests in water $8°/oo$ (1), $30°/oo$ F_2 (2); $35°/oo$ F_2 (3), and $40°/oo$ F_3 (F_2 from $35°/oo$) (4); б — tests in water $8°/oo$ (1), $18°/oo$ F_1 (2), $5°/oo$ F_1 (3), and $3°/oo$ F_1 (4).

Key. Horizontal axis: days

The young also survived at salinities ranging from 30 to 35°/oo. As seen from Table 3, the percentage of survivors (reaching sexual maturity) of the F_1 generation reached maximum in the control sample. In these conditions 97°/o of the larvae survived — that is, practically all of the larvae — because the loss of 3°/o can be considered as a natural chance, as well as a chance error of the experiment. In water with salinities of 5 and 3°/oo, the relative number of surviving F_1

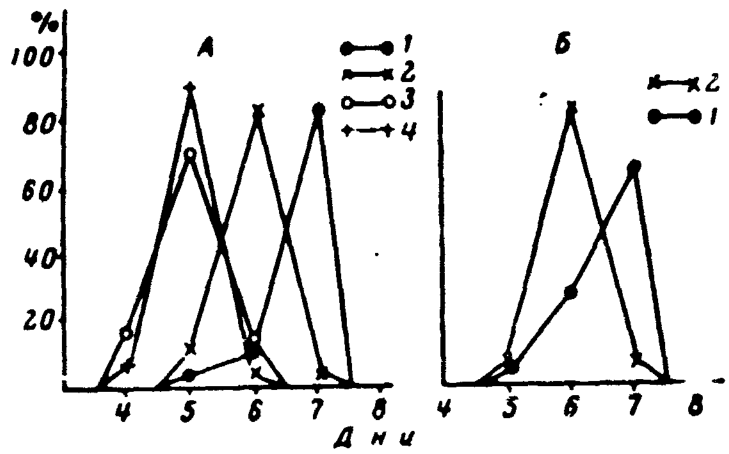

Fig. 2. Mean number of larvae of S. bellulus leaving spawns in certain days (in °/o of the total number of larvae in spawns).

A — tests in water having the salinity of 35°/oo; F_1 larvae: 1 — of spawns deposited on the 2nd day since the parents are kept in a given salinity; 2 — of spawns deposited on the 8th and 9th days; 3 — of spawns deposited on the 14th and 15th days; 4 — F_2 larvae; Б — tests in water having the salinity of 40°/oo; F_3 larvae of F_2 mollusks raised at 35°/oo; 1 — of spawns deposited on the 2nd to 3rd days since the parents are kept in a given salinity; 2 — of spawns deposited on the 5th to 7th days.

Key. Horizontal line: days.

mollusks decreased somewhat. An increase in the salinity of water diminished the survival of young mollusks in comparison with the control sample — at the salinity of 30°/oo the number decreased three times;

at 35°/oo, almost 10 times. The young mollusks perished mainly in the earliest stages of development. It is seen from Fig. 3 that all of the mollusks that perished at 30°/oo were smaller than 1.5 mm, but at 35°/oo the corresponding size did not exceed 1.0 mm. The mollusks that were able to reach the indicated "critical" sizes survived to the end of the test. Another test was set up for the survival and growth of young in water having the salinity of 40°/oo, but it was impossible to carry it out to the end. The test continued for 11 days and was interrupted when the young reached the average size of 1.1 mm. Only 7°/o of the mollusks remained alive at the end of the test. These data allows us to assume that the survival and growth of S. bellulus is possible at 40°/oo.

Table 3

Survival of Young S. bellulus in Water having Various Salinities

(in °/o of the original number of larvae)

Young	Salinity, °/oo					
	3	5	8	30	35	40
F_1	76	78	97	30	10	7*
F_2	89	—	—	88	75	—

*F_3 of F_2, born at 35°/oo.

A considerable increase in the relative number of surviving F_2 mollusks in comparison with F_1 generation was observed.

The growth of the young was studied in tests with water having the salinity of from 3 to 35°/oo. As seen from Fig. 4, a small increase in the size of animals in the control samples was observed as early as the age of two days. Further, during 8-9 days, the growth of the mollusks is rather intense. At the age of 11 days the mollusks reach their maximum size and the growth ceases. A decrease in the salinity of water creates a certain decrease in the rate of growth of F_1 /204 generation. At $5^o/_{oo}$ a noticeable retardation by two to three days in the growth of the mollusks was observed in the first period of life when comparing the phenomenon with the control sample; later, at the age of five to six days, the growth rate increases and during the subsequent six days it is comparable to that of the control samples.

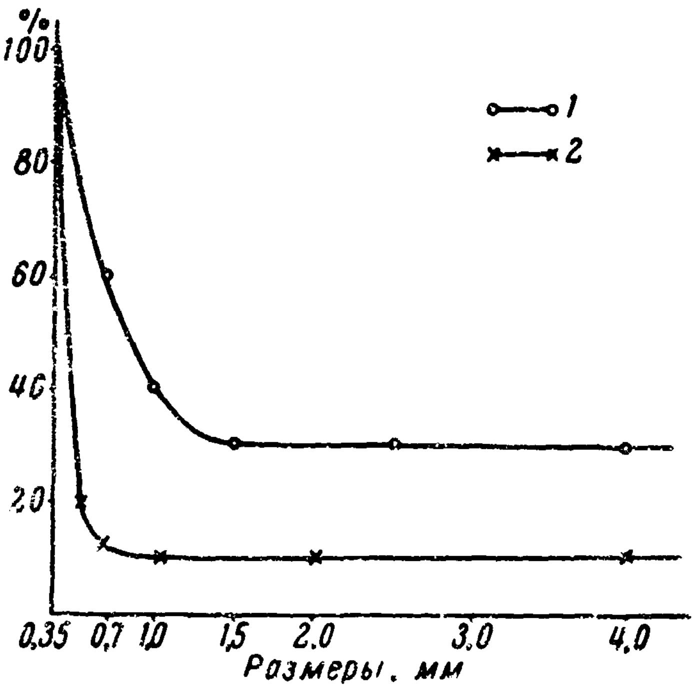

Fig. 3. Relation between the number of surviving young S. bellulus (in $^o/_o$ of the initial number) and their sizes at 30 (1) and $35^o/_{oo}$ (2).

Key. Horizontal line: size, mm.

However, when the animals reach the age of 12-13 days the growth rate at $5^o/_{oo}$ sharply decreases and ceases altogether, whereby, at this salinity the mollusks do not reach the size of mature animals living in normal conditions as shown by control samples. The retardation of growth is still more noticeable in young mollusks at $3^o/_{oo}$. In these conditions, the entire growth curve runs noticeably below the curve of the control samples, whereby in the case of very young mollusks the retardation was of the same proportion, as in the mollusks kept at $5^o/_{oo}$, while in the case of more mature individuals - at the age of 9 days or more - the growth curve at $3^o/_{oo}$ runs noticeably below the growth curve of mollusks kept at $5^o/_{oo}$. Mature animals that have grown up at $3^o/_{oo}$, as seen from Fig. 4, are approximately 11 mm shorter than the control animals and 0.5 m shorter than the mollusks that have been kept at $5^o/_{oo}$.

The growth curve of the F_1 generation kept at a salinity of 30°/oo compares with that of the control samples during the first days of life; later the rate somewhat deviates from it so that the mollusks reach the maximum sizes of control animals two days later; the growth

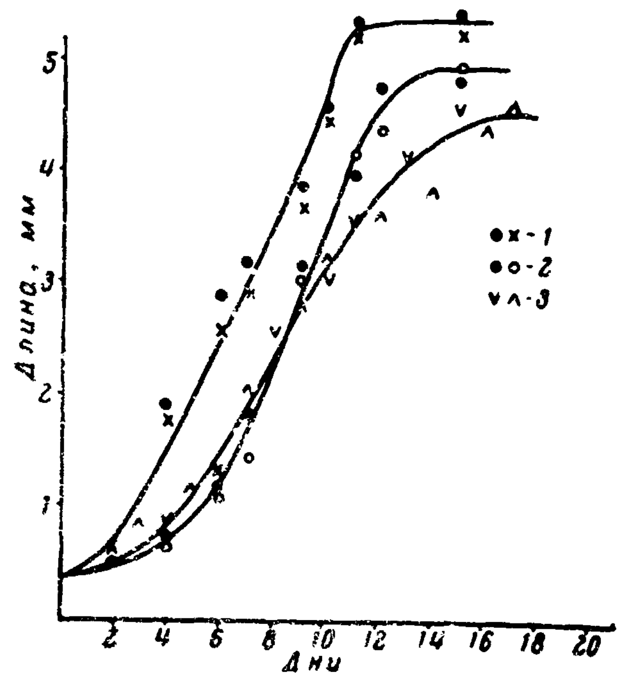

Fig. 4. Growth of young S. bellulus at 8 (1), 5 (2), and 3°/oo (3). The test was repeated twice for each salinity.

Key. x-axis: length, mm
y-axis: days.

curve of the mollusks of the F_2 generation at 30°/oo compares with the growth rate of the control animals (Fig. 5).

The greatest retardation of growth was observed in the F_1 generation, developed from spawns, deposited in the first days by parents kept at the salinity of 35°/oo (Fig. 6). These young mollusks almost did not grow during the first 10 days of their life; but during the subsequent 10 days (from 10 to 20) the growth was very intense, so that the growth rate was comparable to that of the control sample, and the size of mature animals equalled the size of mature animals that had been raised

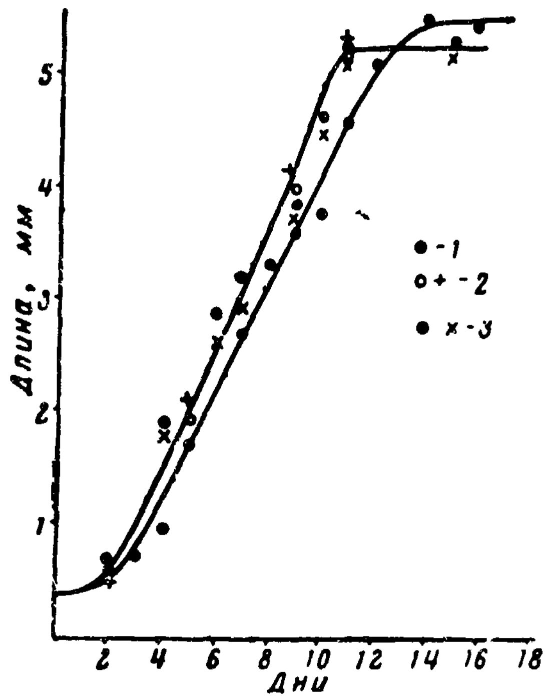

Fig. 5. Growth of young S. bellulus at 30°/oo of F_1 (1) and F_2 (2) generations, as well as at 8°/oo (3). Tests 2 and 3 were twice repeated.

Key. x-axis: length, mm
y-axis: days.

in control (natural) conditions. A somewhat smaller retardation of growth in the early period of life was observed in young F_1 mollusks of spawns, deposited during the 10th to the 12th day since the parents had been kept at the salinity of 35°/oo (F_1 later). A considerable retardation of growth could be noticed only during the first five to six days of life, after which the intensity of growth, as in the case of F_1 (earlier), was comparable to the control animal. The smallest retardation of growth (during one to two days) at 35°/oo was observed in F_2 mollusks. Their growth curve runs parallel to that of the control animals, being behind only by one day. /206

All of this allows us to assume that during the early period of young individuals of S. bellulus the processes of the formation of the organism, which, as in other animals, can be retarded by unusual conditions of increased salinity for a given population. It is possible that the processes are associated with a changeover of the respiratory apparatus of the mollusks and the beginning of the formation of cerata (branchial processes) on the back, the rudiments of which appear in animals having the size of 0.7-0.8 mm. After the animal has survived this, evidently, critical phase, the intensity of growth is compared to that of the control animal and all the processes reach their normal level.

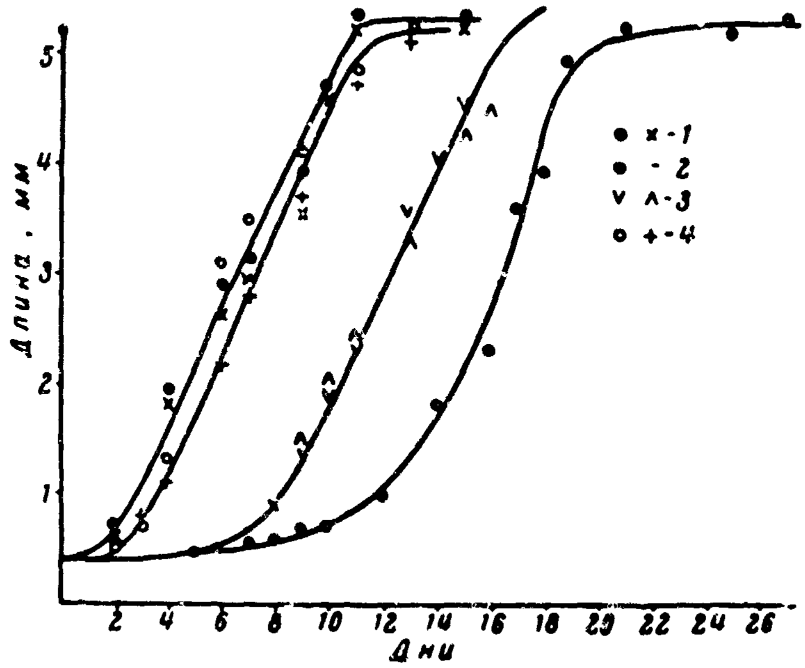

Fig. 6. Growth of young S. bellulus at 8°/oo (1) and at 35°/oo F_1 of early spawns (2), F_1 of late spawns (3) and F_2 (4). The test was repeated twice, except for salinity 35°/oo.

Key. x-axis: length, mm; y-axis: days.

When examining the mean values of growth coefficients for the entire growth period of F_1 mollusks kept in various salinities (Table 4), an increase of the values, in comparison to the control values, is evident either with a decrease or an increase in the salinity of water. The most insignificant decrease of the mean growth coefficient of the mollusks was observed at 30°/oo, the value being 4°/o; the greatest decrease was at 35°/oo of the early F_1 mollusks — namely, 21°/o.

Table 4

Values of the Growth Coefficient of S. bellulus Kept in Water Having Various Salinity Concentrations

Days	Salinity, °/oo 3	5	8	30		36		
	F_1	F_1	F_1	F_1	F_2	F_1 earlier	F_1 later	F_2
1								
		0,35			0,65			0,65
2			0,87	0,64				
	0,70						0,10	0,92
3		0,60				0,23		
			3,75	0,87	1,33			1,41
4				2,86				
5	0,87	0,50	0,98				0,74	1,90
6				1,38		0,34		
		4,18	0,67					0,80
7	2,30				1,18		1,31	
				1,50		0,52		
8		1,81	0,87					
				0,74			4,07	1,13
9	0,82		1,81	0,51		0,36	2,80	
10		1,26			1,36			
	1,56		1,49	2,01			1,96	0,98
11						0,69		
		1,32	0	1,18	0			
12	0,70						1,46	0,56
			0		0			
13				0,49		2,70		
14	1,09	0,28					1,68	0
				0		1,83	2,36	0
15		0		0			1,30	
16	0,15	0				0,74	0,56	
17	0					1,40	0	
18	0					4,22		
19							0	
20						0,59		
21								
						1,21		
22								
23						0		
k mean	0,92	1,01	1,13	1,08	1,13	0,89	0,88	1,05

Only in one case was the mean growth coefficient of F_2 mollusks kept at $30^\circ/_{oo}$ equal to that of control animal (1.13). In F_2 mollusks kept at $35^\circ/_{oo}$, the value was below that of the control animals by $7^\circ/_o$.

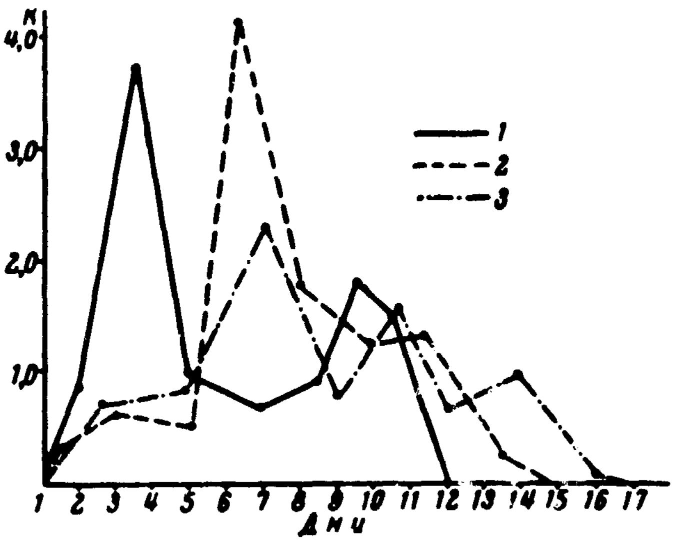

Fig. 7. Curves of S. bellulus growth coefficient at 8 (1), 5 (2), and $3^\circ/_{oo}$ (3).

Throughout the entire period of growth its intensity varies considerably (Table 4; Figs. 7-9). The curve of the growth coefficient of the control sample has two maxima: between the 2nd and 5th days, when the growth coefficient reaches 3.75, and between the 8th and 11th days, when the growth coefficient rises to 1.81. Between the maxima a considerable decrease of the growth coefficient is observed between the 5th and 8th days, its value being below 1.0. Thus, two periods of intense growth are observed in young animals kept in control (natural) conditions; these periods are separated by a period of relative retardation of growth. Undoubtedly, the first maximum of intense growth is accompanied not only by a general increase in the size of the mollusks, but also by considerable morphophysiological changes in organism, which are associated with the formation of the respiratory apparatus. Evidently, during the formation of sexual glands the growth decreases.

Changes in the coefficient of growth, the form of growth curve, and data on the fertility of S. bellulus enable us to conclude that at $8^\circ/_{oo}$ the lowering of the intensity of growth in mollusks five to eight days old is determined by their sexual maturing. The retardation of growth continues to a relative stabilization of fertility, after which a period of intense growth sets in and is accompanied solely by increase in the size of the animal.

By examining the growth coefficients of S. bellulus in water having a decreased salinity (Fig. 7), it can be readily noticed that the form of curves differs from the data of control samples. The growth coefficient of mollusks kept at 5°/oo was extremely low (about 0.5) during the first five days. Later, after the fifth day, i.e. during the time when a decreased intensity of growth began in the control animals, the growth coefficient began to increase, exceeding even the first maximum of control samples. A decrease in the growth coefficient on the eighth day corresponded to the mean sizes of animals, namely about 3 mm (see Fig. 4), i.e. to the beginning of the reproduction period. However, the second increase in the growth coefficient at 5°/oo, which is typical of control animals, was not observed. The growth intensity of mollusks kept at 3°/oo was low during the first five days. Later, as /209
in the case of mollusks kept at 5°/oo, the growth coefficient increased during the same time; however, its value was almost twice as low as the growth coefficient during the first maximum in the control animals and in animals living at 5°/oo. Further, small fluctuations in the growth coefficient, which was generally decreasing, were observed. It is possible that the variation in the form of curves of the growth coefficient at salinities 5 and 3°/oo, in comparison with that of the control animals, is associated with the reaction of mollusks to a diminished salinity concentration.

With an increase in the salinity, variations in the form of a curve characterizing the growth coefficient are also observed in the F_1 mollusks (Fig. 8). At 30°/oo the form of the growth curve deviates from that of the control sample, because the growth of the mollusks is rather retarded in the early stage of growth. The general form of the curve of growth coefficient at the salinity of 30°/oo is very near that of the control sample.

A pronounced change in the curve of the growth coefficient is observed in the early stages of the F_1 generation living in water having a salinity of 35°/oo (Fig. 9). While the control animals grew to maturity, the growth coefficient of young mollusks of the early F_1 generation raised at 35°/oo remained below 1.0. A considerable increase in the intensity of growth was observed in the animals only in 11 to 12 days, which continued to 15-16 days; during this time the growth coefficient reached 2.7. Afterwards, between the 15th and 19th days, the growth intensity diminished, whereby the animals began to deposit spawns. Between the 18th and 20th days, one more very intense increase in the intensity of growth occurred, the value of the growth coefficient reaching 4.22. Such an inverse position of peaks, relative to the

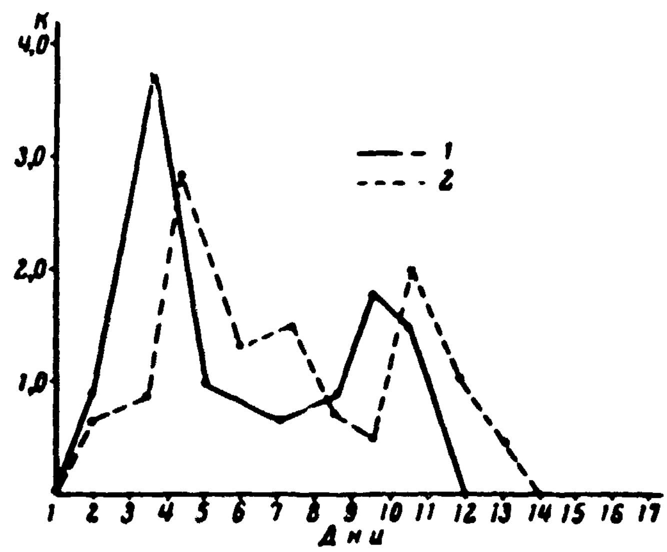

Fig. 8. Curves of growth coefficient of S. bellulus at 8 (1) and 30°/oo (2).

control samples, on the growth curve of young mollusks of the early generation of F_1 mollusks, as well as the retardation of growth during the first 10 days of life, may be associated with the effect of high salinity. Also in young mollusks of the late generation of F_1 mollusks one can observe a delay in the rise of the growth curve. A pronounced rise occurs between the 7th and 11th days, when the maximum value of growth coefficient reaches 4.0. Later, as in the case of the control animals, a three day decrease in the growth coefficient and a second /210 increase of it are observed, whereby the value of the second rise was almost twice smaller than the value of the first rise. As to the position relative to the abscissa, the growth curve of F_2 is identical to that of the control sample. Also the form of the curve is reminiscent of the growth curve of the control animals; however, the peaks of growth are smoothed on this curve, which attests to the relative uniformity in the growth of young F_2 mollusks at 35°/oo.

The calculations demonstrate that the growth coefficient is thoroughly applicable to the investigation of growth in invertebrates having a short life cycle. The form of the growth curve testifies to the discontinuity of the growth process in S. bellulus living in normal conditions. With a change in the salinity of the medium, one can, evidently, observe displacements of discontinuities of growth with time, as well as variations in the values of the discontinuities in animals that have not yet adapted themselves to the new conditions. Such deviations in the curves of growth coefficients of animals kept in changed living

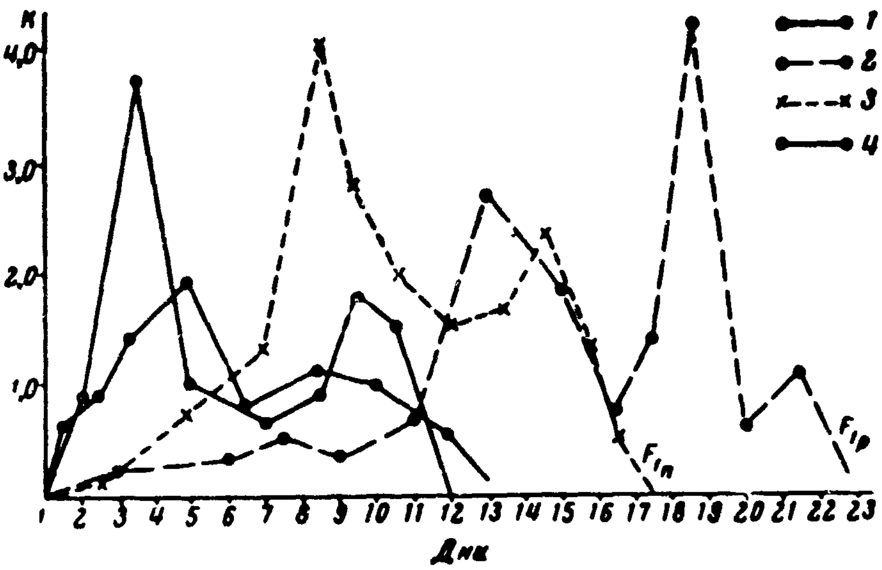

Fig. 9. Curves of growth coefficients of S. bellulus at 8°/oo (1) and at 35°/oo F_1 (early) (2), F_1 (late) (3) and F_2 (4).

Key. Horizontal line: days.

conditions from the curves of growth coefficients of the control animals, as well as variations in the values of the mean growth coefficient, express the degree of adaptability of animals to the new conditions of the medium. In animals that have completely adapted themselves to the changed salinity conditions, the mean growth coefficient and the curve of growth coefficient must coincide with the respective values of the control sample.

DISCUSSION OF RESULTS

Experimental studies in the reaction of the Azov population of S. bellulus to water having a different salinity elucidated the ability of the animals of this population to go on living and developing within a wide range of salinity (Table 5). The upper limits are based on the results of observations on F_2 mollusks, which had been accustomed to living in laboratory conditions in water having a salinity of 35°/oo.

Table 5

Salinity Limits for Various Stages in the Development of the Azov Population of S. bellulus

Indicators	Salinity, °/oo	
	from	to
Survival of mature individuals.	3	55
Spawning.	3	50
Development of larvae	3	45
Larvae leaving their spawns	3	40
Survival of young	3	40
Growth of young	3	35(40)

The most resistant to variations of salinity appeared to be mature animals, the least resistant being larvae during the period of metamorphosis from veligers to young mollusks and the young mollusks in the initial stage of development (to the beginning of cerata formation). The salinity limits for these stages appeared to be 3 and 40°/oo. The other processes of S. bellulus (spawning and development of larvae — veligers — within spawns) were observed within 3 - 45 - 50°/oo. The same phenomenon of differences in salinity limits for various stages of development was observed before (Nikitin and Turpayeva, 1957; Turpayeva, 1961; Turpayeva and Simkina, 1961). However, in these cases the representatives of the Black Sea populations had been discussed and the differences between the limits of decreased salinity for various stages of development had been pointed out. As to the Azov population of S. bellulus, which inhabits water whose salinity is evidently near the limit for the existence of the species, the lower limit of salinity appeared to be the same for all the stages of development that were investigated. Differences in the limits of salinities are observed only when the salinity is increased to a degree the animals have never encountered and which exceeds by far the fluctuations of salinity in their natural habitat.

Thus, the processes of growth and life in the Azov population of S. bellulus occur normally within 3 to 40 °/oo. Within this salinity range one can observe spawning, development of larvae, transition from the veliger stage to new mollusks, growth of young, etc. The ability of the animals, inhabiting brackish waters, to preserve their life's function at a normal level within a very wide salinity range, often to the oceanic concentration, has been repeatedly mentioned in literature (Kreps, 1929; Karpevich, 1947, 1955; Zhirmunskiy, 19[illegible]; Soldatova, 1961; Turpayeva, 1961). Such an ability was considered as a consequence of marine origin when the progenitors had entered the seas from the ocean. The results of this study confirm once more this concept.

With a variation of salinity from 3 to 40 °/oo, especially in cases when it approaches the limits, considerable changes in the mentioned processes are created in S. bellulus. The resultant data made it possible to single out two types of such changes: a decrease in fertility of mature animals and a partial elimination of larvae and young animals, on the one hand, and a retardation and change of the character of development, on the other hand. Thus at 3, 40, and 45 °/oo the diurnal fertility of mature animals (see Table 1) decreases considerably in comparison with the normal level. At 3 °/oo only 27 °/o of the F_1 larvae left the spawns (see Table 2), but at 40 °/oo all of the /212
larvae of the generation perished. At intermediate salinities, from 5 to 35 °/oo, the relative number of larvae leaving their spawns did not change, but the number of surviving young changed considerably (see Table 3); whereby a decrease of salinity created a considerably smaller number of deaths in F_1 mollusks than an increase of salinity. With an increase of salinity to 30 °/oo, only 30 °/o of F_1 mollusks survived, but with an increase to 35 °/oo the corresponding rate was 10 °/o, while at 3 °/oo the main mass of young leaving their spawns reached sexual maturity.

Such a partial elimination of larvae and young mollusks of the Azov population of S. bellulus by changes in salinity can, undoubtedly, be considered as a manifestation of a variable endurance of individuals of the same population with respect to changes in salinity.

A retardation of development was observed when the rate of development of larvae and the growth of young S. bellulus was investigated. Thus, when the salinity was decreased to 5 °/oo the development of the main portion of F_1 larvae is delayed by a day; but when it was decreased to 3 °/oo the delay for the F_1 larvae was two days (see Table 1). An increase to 30‰ also delays the development of the major portion of larvae by a day; the delay is especially noticeable in F_1 mollusks when the salinity is increased from 35 to 40‰ (see Fig. 2).

The period of retardation in the development of the animals, especially at an early age, depended on salinity concentrations at various periods; after these periods, a restoration of growth rate occurred and the mollusks reached the size of mature animals. The total growth period of the mollusks was considerably expanded; for instance, at 35‰ (see Fig. 9) the early F_1 mollusks reached the size of mature animals in 21 days after leaving the spawn, while the control animals reached the size in 11 days.

Not only the retardation of growth and the increase of its period occurred as a result of salinity variation. Often one could also observe variations in the character of growth. As was already mentioned, two brief periods of intense growth were observed in water whose salinity was normal for S. bellulus (8‰); during the first period, the growth coefficient reached 3.75, but during the second period it was 1.81; a period of less intense growth rate with the coefficient being less than 1.0, was observed between the two peaks, during which the development of sexual glands accompanied by an increase of fertility took place. A decrease in the salinity of water changed the character of the growth curve considerably, delaying the arrival of the first period of intense growth rate and causing a gradual cessation of growth without the formation of a pronounced retardation period during the sexual maturing. An increase in the salinity of water to 30‰ (see Fig. 8) created only an insignificant (one day) retardation of the first period of intense growth rate, but it was not reflected in the character of the curve. However, at 35‰ (see Fig. 9) one could observe in the early F_1 mollusks not only a lengthy (10 days) retardation of the first period of intense growth rate but also a change in the character of growth curve, which was less intense during the first period and increased during the second period, evidently, for the sake of compensation. In contrast to the tests with water having a decreased salinity, one could not observe a gradual cessation in the growth rate at 35‰; the period of its decrease in connection with sexual maturing remained clearly pronounced.

All of the quantitative changes in the processes we have discussed are most clearly pronounced in F_1 mollusks. However, even in this generation one can observe a partial smoothing in the intensity of certain processes as a result of adaptation of progenitors. The adaptation of the animals to variations of salinity is manifest, in their generation, by a decrease in the period of larval development within the spawn and by a decrease in the period of growth retardation in the early stages of the development of young mollusks.

Thus, in spawns deposited by individuals of the generation on the second day of the experiment, at 35°/oo, the greater portion of larvae developed within seven days (see Fig. 2, A); in spawns deposited on the 7th and 8th days, the larval development lasted six days; but in spawns deposited on the 14th and 15th days, the development lasted five days. In spawns deposited by the mollusks (which had been raised at 35°/oo) on the second day of the experiment in water with a salinity of 40°/oo (see Fig. 2, Б), the major portion of larvae developed in seven days, but in the spawns deposited on the 5th to 7th days, the larvae developed in six days. The total growth period of young mollusks, coming from spawns, deposited on the 7th and 8th days by P individuals in water having the salinity of 35°/oo (F_1 earlier) was 21 days (see Figs. 6 and 9); a considerable retardation of the growth rate of the mollusks was observed in the first 11 days (the growth coefficient was smaller than 1.0). The total growth period of the mollusks, coming from spawns, deposited by P individuals (F_1 later — see Figs. 6 and 9) in water having the salinity of 35°/oo, on the 14th and 15th days was decreased to 17 days, but the retardation of growth during the initial period lasted only six days ($k < 1.0$).

The adaptation of mature individuals to a salinity of 35°/oo was manifest not only in the decrease of the period of larval development and in the growth of the young, but it was also reflected in the restoration of the general character of growth, which had been impeded by the change of salinity. The growth curve of early F_1 (see Fig. 9) at 35°/oo preserved its two apexes, but the first peak was considerably lower than the second one, whereas in the control animals the first peak of the growth curve was twice as high as the second one. The form of the growth curve of F_1 mollusks (late) is identical to that of the control animals.

Thus, some of the processes are restored almost to a normal level during the life span of a generation. However, a complete adaptation to such a high salinity level, as 35°/oo, does not occur within the life span of one generation. The growth rate of young mollusks kept at 35°/oo approximated the growth rate of the control animals kept in normal conditions only in the F_2 generation, when the total development period of young decreased to 12 days. Analogous phenomenon was observed at 30°/oo. Despite a very great deviation of growth rate in the young of F_1 generation that live in these salinity conditions, a complete equalization of growth rate occurs only in the F_2 generation. The mean growth coefficient of young F_2 mollusks at 30°/oo appeared to equal the value of the control animals (see Table 4).

In addition to the adaptation process of individuals to changes of salinity, established by the resultant data, one more way of adaptation of the species to new conditions of the medium is traced - namely, selection of the mollusks that are the most resistant to the effect of salinity. As was already mentioned, a partial elimination of the young of the F_1 generation decreases its survival in high salinities (see Table 3). However, in the F_2 generation, whose parents have been most resistant to salinity changes in comparison with other individuals of the population, the number of survivors in the growth process of mollusks was incomparably higher than in the F_1 generation. Thus, at 30°/oo the relative number of surviving F_2 mollusks increased in comparison with F_1 mollusks by 58°/o, at 35°/oo the value being 65°/o; a small increase in the survival rate of F_2 mollusks was also observed at 3°/oo — namely, by 13°/o. The selective process is still more noticeable when the salinity is increased to 40°/oo. The development of larvae at 40°/oo and their leaving of the spawns in a quantity, approaching that of the control samples (80°/o), were observed only in cases when the spawns had been deposited by mollusks that had been raised in water with a salinity of 35°/oo.

Thus, the adaptation of S. bellulus to new salinity conditions was twofold in the tests: the adaptation of mollusks during two generations, and the selection of individuals that can best endure the variations of salinity. At insignificant variations of salinity, the adaptation of the species was based only on the adaptation of individuals; the selection of the most suitable individuals was observed mainly in water having a salinity that is near the limit of tolerance for the species. It is possible that an analogous phenomenon of selection of the most resistant individuals with respect to salinity variations exists in natural conditions when a species colonises new areas having different salinity conditions; only in these experimental conditions the phenomenon is much more pronounced. This phenomenon is evidently reflected in the natural S. bellulus population of Taganrogskiy zaliv, living at the salinity of 8°/oo. Among the mollusks of this population a selection of individuals that are more capable of enduring low salinities had taken place, leading, in all probability, to a combination of the lower salinity limit (3°/oo) for all the processes that were discussed. Cases of such a combination of /214 the lower salinity limit for various stages of development were not known before. On the contrary, noticeable, 2-4°/₀₀, differences between such limits had always been observed. The development stage that is most sensitive to a decrease of salinity appeared to be the larva either during the period of transition from trochophore to veliger (Nikitin and Turpayeva, 1957), or during the period of settlement (Pasternak, 1958; Turpayeva, 1961). In the given case, obviously by the selection of the most resistant individuals, a combination of the lower salinity limits of various stages of development had taken place at a level (3°/oo) below which even a brief existence of mature organism is impossible. The selective process also determines the high percentage of survival of F_1 mollusks at 3°/oo (76°/o, see Table 3), which shows that the major portion of individuals of the given population endures a decrease of salinity. However, a general retarding effect of extreme salinity limits on the life and development of S. bellulus is preserved;at 3°/oo one can observe a decrease in the fertility of mature individuals, a decrease in the relative number of survivors, an increase in the period of larval development, a decrease in the growth rate of the young, and a distortion of the character of growth.

Thus, it can be assumed that S. bellulus, having relatively recently entered the Sea of Azov, fully utilizes its capability of mastering the new conditions. In order to substantiate this supposition, analogous experiments have to be conducted with the mollusks of the Black Sea population of S. bellulus.

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ECOLOGY OF THE HYDROID POLYP PERIGONIMUS MEGAS KINNE — A NEW SPECIES IN THE FAUNA OF THE USSR

Abstract

In 1960 *Perigonimus megas* Kinne — a new species for the Sea of Azov — was found in the water supply system of a metallurgical plant. The settlement of larvae occurs in spring with water temperature rising above 15°C. The biomass of stolons reaches 10 kg/m^2 by June-July. A series of experiments was conducted on the growth rate of *Perigonimus* in water of various salinities (8, 5, 3, 2, 1‰). Lowering of water salinity brings about progressive destruction of the animals, although 15% of them endure water salinity of 1‰ for a month.

Perigonimus megas Kinne was not known in the Sea of Azov up to the present time (Mordukhay-Boltovskoy, 1960). E. P. Turpayeva and I encountered it for the first time in 1960 in the Zhdanov area, later in Kerchenskiy proliv on the coast of Kamysh-Burunskiy poluostrov (Kamysch-Burunskiy p.). During the last years it was found also in the Caspian Sea (Zevina, Kuznetsova, and Starostin, see this compilation of papers).

This species is found in masses in the fouling of the water supply system of the metallurgical plant situated on the north coast of the Sea of Azov. *Perigonimus megas* is found on stones and the dam adjacent to the plant in the sector of Taganrogskiy zaliv, but it never forms such a continuous cover as in water conduits; its colonies are smaller and the quantity of hydranths and gonophores is relatively smaller in the colonies. In comparison with hydroids living on dams, those inhabiting the sea always seem to be stunted. Of course, the rapid flow of water in the conduits creates especially favorable conditions for the growth of *Perigonimus megas*.

Kinne (1956b), in his diagnosis of the species, points out that *Perigonimus megas* is characterized by a pseudohydrotheca, and its gonophores lie on the feet of the polyps. The female gonophores are 0.3 mm long and have one egg, the male gonophores being 0.6 mm long. The hydranths are about 0.6 mm (0.4-0.7 mm) long, and have 9 to 12 (7-15) tentacles forming a crown around the tubercle of the mouth. The colonies are about 20 cm long, consisting of irregular branches and having a rather firm periderm. This is a brackish water species. In the Kiel Canal it propagates in June, July, and August at temperatures above 14°C.

Kinne described the Perigonimus megas of the Kiel Canal, where, according to the opinion of this author, it was misidentified for a long time. Thus, Funk (cited by Kinne, 1956c) presents a polyp which is completely identical to Perigonimus megas, naming it Bougainviilla ramosa Less. Hummelinck (1936) and Vervoort (1946) name the polyp Cordylophora caspia f. lacustris-f. typica, although the external form, number, and position of tentacles, pseudohydrotheca, and structure of gonophores leave no doubt that this hydroid is Perigonimus.

In order to support the correctness of the opinion of Perigonimus as a form of Cordylophora, Hummelinck cites his observations when the runners of f. lacustris grow from the stolons of f. typica. Kinne is convinced that in this case Hummelinck had observed the primary colonies of cordylophores, which had grown as an epizoon on the old stolon of Perigonimus. It is possible that in the Sea of Azov, as in the Kiel Canal, the Perigonimus has been misidentified as Cordylophora.

According to data found in papers and according to the results of my observations, the Perigonimus and Cordylophora have the following differences: /217

Perigonimus	Cordylophora
Tentacles lie along the tubercle of mouth forming a crown	Tentacles lie allover the body of the hydranth
Characterized by pseudohydrotheca	Pseudohydrotheca is absent
Dioecious colonies	Hermaphroditic colonies
Only one egg develops in female gonophores	As many as 15 eggs develop in female gonophores

Perigonimus megas, found by me in the Sea of Azov, is completely identical to the one described by Kinne and obtained from the Kiel Canal. Of course, individual colonies reached the length of 30-35 cm, while in the Kiel Canal, where the species inhabits wooden wharves, its length does not exceed 20 cm. It is possible that this is associated with favorable living conditions in the Sea of Azov, long vegetational periods, abundance of food, relatively high water temperature, etc.

This paper discusses some of the ecological features of the Azov Perigonimus in natural conditions, presenting the results of experimental investigations of the effect of various salinity concentrations on the colonies of this polyp.

The Perigonimus was described by Kinne in 1956. The only study of the species (Kinne, 1956c) is based on the examination of preserved material, elucidating in fact only the distribution of the species in the Kiel Canal. There are no studies discussing the species inhabiting the Sea of Azov.

OBSERVATIONS IN NATURE

Reduction and regeneration. Sometimes the hydranths, which are reduced when unfavorable conditions develop in a medium, are absent from the stolons of *Perigonimus megas*.

A typical process of reduction is as follows: the hydranths draw in their tentacles, wrinkle, and shrink, and, at last, disappear under the periderm of the stolon. Later, with unfavorable conditions, the reduction process embraces the entire colony. The soft body shrinks, as a result, and is divided into segments so that parts of the periderms of the stolons remain empty.

The reduction process does not begin simultaneously in all the sectors of a given colony. As a rule, the oldest polyps near the primary polyp are the first ones to become reduced, often the primary polyp being the leader in the process. The basic stolons preserve their soft body the longest. Probably, i-cells (interstitial cells?) accumulate here and serve as reserve buds.

Resistance against unfavorable conditions of the surrounding medium differs with various parts of a polyp. Gonophores are least resistant at the moment they are produced, then follow the old polyps, the slightly more resistant young polyps; afterwards, follow the mature polyps, branches bearing polyps, and, lastly, the most resistant stolons. After the reduction of hydranths, the "stolon phase" sets in the colony of hydroids; this phase is characterized by a reduction of all the processes of life to a minimum. In the "Azovstal'" plant area, *P. megas* has the "stolon phase" from November to April. A transition to this phase occurs with a decrease of water temperature to 9-10°C and below.

According to I. V. Starostin and Yu. Ye. Permitin (see this compilation of papers), the mass reduction begins in the conduits of the water supply system of the plant by the separation of the upper portions of the stolons, which are brought onto the filters of the water supply system, clogging them and creating serious hindrances in operation. The water conduits are not, however, completely cleaned: the lower portions of the stolons with remains of the soft body remain and serve as hibernating buds. In the spring, as soon as the water temperature exceeds 9-10°C, new hydranths appear and a rapid growth of stolons commences.

In contrast to the slow "primary" growth, during which a colony begins to grow from the primary polyp, this "secondary" growth is called regeneration.

Settlement of larvae. In April-May, when the water temperature reaches 15°C, the larvae of P. megas begin to form settlements. Tiny (1.5-2 mm) floating larvae covered by cilia are hatched from the female gonophores and carried away by water currents. Glands secreting a viscous matter are evidently found on the front part of such a larva, which enables it to adhere rapidly to an object. Usually in about four to five hours a tubercle — which is a rudiment of the primary hydranth — appears on the free (rear) end of the larva; the beginnings of tentacles are noticeable after awhile in its upper part. In a few hours a pair of tentacles is formed. The base of the cephalic polyp begins to develop gradually, forming primary stolons creeping along the object. New hydranths appear on them; after a while, branches of the first order ramify from the stolons upward; later hydranths and branches of the secondary order appear on the stolons.

The primary growth, which is slow at the beginning, intensifies in three to four days. According to observations by I. V. Starostin and E. P. Turpayeva (see this compilation of papers), a dense network of hydroid stolons developed in the summer on panels that had been in water for 10 days; often the entire surface of the glass was covered by them. Such a network could have been formed of four to five colonies, so that in 10 days lateral ramifications with one to five hydranths had a chance of developing. The weight of hydroid fouling on the glass having 90 cm^2 of surface amounted to 5 g during 10 days of June 1961, and to 13.5 g during the same period in August. Mass development of hydroids occurs in July-August. In July 1960 the biomass of P. megas reached 10 kg/m^2 on the underwater part of hydrotechnical structures in the Sea of Azov (Starostin and Permitin, see this compilation of papers). According to my observations, the colonies of P. megas reached their maximum development during this time.

Enemies. In the water supply system of the "Azovstal'" plant one can observe a considerable development of two animals — natural enemies of P. megas.

Nudibranchiate mollusks Stiliger bellulus (d'Orbigny) appear on stolons in June, soon reaching their maximum development. More than seven thousand large specimens (4-5 mm long) of the mollusk weighing about 100 g were observed in July 1961 on the colonies of hydroids. S. bellulus feeds on the body of the hydroids, gnawing at the new segments of stolons and the developing buds, but it also destroys mature hydranths. One nudibranche 5 mm in size can destroy as many as 100 mature hydranths (Turpayeva, see this compilation of papers).

The Dutch crab Rhithropanopeus harrissi tridentatus Maitland appears in mass in August. As many as 1500 individuals of young crabs were observed in water conduits of the plant during the second half of the summer at 1 m^2. Hiding among stolons of hydroids, the crabs feed on them. By gnawing through the thick stolons of large colonies, the crabs further the separation of small segments of stolons in great numbers, which may again become attached to objects and initiate the creation of new regenerated colonies.

EXPERIMENTAL INVESTIGATIONS /219

The initial data on the raising of P. megas colonies in laboratories were obtained from the grids of TETs (Heat and Electric Power Plant) (brought from the sea). The salinity of water in the area fluctuated from 6.8‰ in April to 8.2‰ in August. The stolons taken from the filter grids of TETs had female gonophores. The lumps of stolons with female gonophores were cut off and placed in Petri dishes about 10 cm in diameter and 1.5-2 cm deep. The thickness of the water layer in the dishes was, as a rule, 1-1.5 cm. Larvae came out of the gonophores in one day; part of them had already been transformed into primary polyps. The water surface in the dish was so large in comparison with depth that the restoration of oxygen occurred readily by means of diffusion. This excluded entirely a lack of oxygen for the polyps. The water was changed daily in the dishes. The hydroids were fed daily on plankton cirripedians <u>Calanipeda aquae dulces</u>, which were washed three times in the water of required salinity. As a rule, the cirripedians remained alive. Two series of tests were set up. In the first series each of the colonies obtained the same amount of food: one or two cirripedians per colony, no matter what the amount of hydranths was in the colony. In the second series each hydranth obtained, as a rule, one cirripedian a day. Thus, a colony with a large number of hydranths obtained a great amount of food. In two to four hours after the feeding, all of the dishes were examined and the food was removed.

The salinity in the first series of tests was 3 and 5‰; in the second series 1, 2, 3, and 5‰. The hydroids kept at natural salinity concentrations for the area — 7.5 to 8‰ — were used as control samples. The first series of tests lasted 21 days, the second 23 days.

Diluted water was obtained by adding fresh water of the Kal'mius river to the Azov water. The physical-chemical properties of the water were determined on the basis of analysis, conducted by the chemical laboratory of the Zhdanov Kokso-Chemical Plant (Table 1).

Table 1

Sea Water		Kal'mius Water
pH	8.7	7.9
Dry residue Cl' SO_4''	11106 mg/1 5400 mg/1 845 mg/1	2102 mg/1 351 mg/1 1029 mg/1
Ca	152 "	9.9 mg · equiv/1
Mg	365 "	7.7 "
Na	1040 "	—
Oxidizability	2.77	—
Alkalinity	—	4.9 mg · equiv/1
General hardness	—	17.6 "

The first series of tests was conducted at the Black Sea Experimental Scientific Investigational Station of the Institute of Oceanology of the AS USSR in June 1961. The primary polyps that had settled in the Zhdanov laboratory at the salinity of 7.4‰ were used as test material. From the day of settlement to the beginning of the test six days had elapsed and the hydranths had already begun to grow. Therefore the mean accretion per unit time in each type of water was used as an indicator of the effect of salinity for the series. The material was divided into three groups. Forty colonies were used as control samples; 55 colonies were put in water with a salinity of 5°/oo, of which 30 were transferred to 3°/oo in five days. The water temperature in the Petri dishes was slowly increasing from 20 to 24°C during the tests.

The other series of tests was conducted in Zhdanov from 3 to 26 July 1961. At the beginning of the tests the segments of the stolons with female gonophores were put in water at a given salinity, where the larvae were hatched and transformed into primary polyps. The water temperature in the Petri dishes fluctuated from 24 to 26°C.

In order to identify individual colonies, charts of their distribution on the bottom of the Petri dishes were plotted; the colonies were numbered, the length of stolons was measured, and the number of hydranths was counted. Later, the measurement of stolons and the counting of hydranths were made regularly, each five to ten days (depending on the rate of growth).

The processing of numerical data consisted of determining the mean length of stolons (M_l). In order to evaluate the dependability of the results, the mean error was calculated by means of the formula

$$S_x = \frac{(M_l - L)^2}{n(n-1)},$$

where M_l denotes the mean length of stolons; L denotes the length of stolons of a given colony, and n denotes the number of colonies in the test.

RESULTS OF OBSERVATIONS

Survival. In the first and second series of tests the survival rate of *P. megas* colonies was identical. Therefore, the results of observations on the survival of *P. megas* colonies in both of the tests were examined jointly (Table 2).

Table 2

Number of Dead, Reduced, and Developing Colonies of P. megas in tests

Salinity, $^{0}/_{00}$	Number of colonies at beginning of test	Died		Did not develop		Developed	
		nos.	$^{0}/_{0}$	nos.	$^{0}/_{0}$	nos.	$^{0}/_{0}$
Control	60	0	0	1	1.8	59	98.2
5	53	14	26.4	8	15.1	31	58.5
3	52	12	23.0	20	38.5	20	38.5
2	21	9	43.0	6	28.5	6	28.5
1	34	28	82	1	3.0	5	15.0

The colonies with empty stolons were considered as having perished. In addition to the depth of the colonies, the primary hydranths repeatedly did not grow. They were periodically reduced and recreated, but they never accepted food or grew. It can be assumed that these primary hydranths were not in a position to pass through the metamorphosis from larva to hydroid polyp. There is no doubt, that with time such primary polyps perish Therefore the development of the colonies was considered as a criterion of their survival.

In conditions that were normal for the form of Perigonimus to be in- investigated, almost all of the tested colonies developed. With a decrease in salinity, the number of growing colonies sharply decreased. /221

Part of the colonies that did not develop during the entire test were in a reduced position, but they did not perish. With a decrease of salinity the quantity of such reduced colonies changed sharply. The smallest number of colonies were in the control tests and at salinities of $1^{0}/_{00}$; the greatest number being at salinities of 2 and $3^{0}/_{00}$.

The quantity of dead colonies was at a minimum in natural salinity conditions; with a decrease of salinity, the quantity increased. In water having the salinities of 5 and $3^{0}/_{00}$, the quantity of dead colonies was the same; a decrease in the relative quantity of growing colonies in the second case was determined by an increase in the quantity of reduced colonies.

Growth of stolons in length and increase in the quantity of hydranths by gemmation are discussed individually for each of the series.

Prior to the beginning of the first series of tests the hydroids were kept for a while in water having a salinity of 8, 5, and 3‰. Therefore, by the beginning of the observations, the number of colonies was different in various salinity conditions. The highest rate of growth was observed in colonies utilized as control samples (Table 3). In

Table 3

Growth of P. megas in Water having Various Salinities
(first series of tests)

Length of test, days	Salinity (‰) and number of colonies											
	8; control n=39				5; n=19				3; n=16			
	Number of capitula	Stolons		Accretion	Number of capitula	Stolons		Accretion	Number of capitula	Stolons		Accretion
		L	$S_{\bar{x}}$			L	$S_{\bar{x}}$			L	$S_{\bar{x}}$	
1	1.1	0.8	0.06	0.0	1.0	0.4	0.036	0.0	1.0	0.2	0.08	0.0
6	1.9	2.1	0.30	1.27	1.1	0.5	0.102	0.14	—	—	—	—
11	—	—	—	—	—	—	—	—	1.1	0.4	0.02	0.185
16	2.6	3.3	0.46	2.5	1.1	0.9	0.17	0.51	1.2	0.6	0.25	0.385
21	2.9	4.3	0.56	3.44	1.1	0.9	0.136	0.54	—	—	—	—

water having a salinity of 5 and 3‰ the accretion was considerably smaller — six to seven times. In these series of tests the accretion of colonies was generally insignificant; even in control samples the mean length of stolons was slightly greater than 1/6, while the average number of the capitulum hydranths constituted 1/5 of the corresponding numbers of the second series (Tables 3 and 4).

In the second series of tests the observations were commenced on the primary hydranths, that had undergone their metamorphosis in water having salinities of 8, 5, 3, 2, and 1‰ (Tables 3 and 4). During the first five days the accretion in all of the tests was insignificant; beginning with the 5th through the 10th days, a considerable increase in the accretion of colonies in the control samples was observed. With salinities of 5 and 3‰ the accretion during this time

Table 4

Growth of *P. megas* in Water having Various Salinities
(second series of tests)

Length of test, days	Salinity (°/oo) and number of colonies																			
	8; control n = 20				5; n = 14				3; n = 11				2; n = 12				1; n = 6			
	Number of capitula	Stolons		Accretion	Number of capitula	Stolons		Accretion	Number of capitula	Stolons		Accretion	Number of capitula	Stolons		Accretion	Number of capitula	Stolons		Accretion
		L	$S_{\bar{x}}$			L	$S_{\bar{x}}$			L	$S_{\bar{x}}$			L	$S_{\bar{x}}$			L	$S_{\bar{x}}$	
1	1.0	0.2	0.0	0	1	0.2	0.0	0	1	0.2	0.0	0	1	0.2	0.014	0	1	0.2	0.0	0
2	1.4	0.6	0.108	0.4	1	0.4	0.04	0.17	1.1	0.6	0.129	0.37	1	1.2	0.016	0.009	1	0.3	0.03	0.08
7	1.7	1.5	0.27	1.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	2.8	2.8	0.54	2.56	1.8	1.6	0.29	1.36	1.8	1.2	0.282	1.02	1	0.3	0.02	0.059	1	0.6	0.07	0.43
15	4.8	7.6	1.3	7.45	3.4	4.6	0.91	4.43	2.3	2.3	0.658	2.12	1.1	0.3	0.132	0.092	1	0.7	0.088	0.46
19	11.2	13.7	1.9	13.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	14.3	27.6	4.28	27.4	5.9	9.5	1.93	9.35	4.0	5.8	1.81	5.6	1.1	0.6	0.25	0.357	1	0.7	0.06	0.53

was 2 to 2.5 times slower than in the control samples, while at salinities of 2 and 1°/oo the accretion was 5 to 6 times slower. As the hydroids were left in the same conditions for 23 more days, the mentioned differences in accretion caused by various salinities were more clearly pronounced. The greatest accretion rate of colonies was observed in control conditions; at 5°/oo the accretion was almost three times smaller than in the control samples, but at 3°/oo the accretion was almost five times smaller.

Table 5

Relative Accretion in the Length of Stolons and the Increase in the Number of Capitula of P. megas Hydranths Kept by Days in Water Having Various Salinities (in °/o of final accretion in control samples)

Length of test, days	Salinity, °/oo									
	7.5–8 Control		5		3		2		1	
	Number of capitula of hydranths	Length of stolons	Number of capitula of hydranths	Length of stolons	Number of capitula of hydranths	Length of stolons	Number of capitula of hydranths	Length of stolons	Number of capitula of hydranths	Length of stolons
5	3.0	1.5	0	0.6	0.6	1.3	0	0.03	0	0.3
7	5.3	4.8	—	—	—	—	—	—	—	—
10	13.5	9.4	6.0	5.0	6.1	3.7	0	0.21	0	1.57
15	28.6	27.2	18.3	16.0	9.6	7.7	0.6	0.33	0	1.68
19	76.7	49.5	—	—	—	—	—	—	—	—
23	100	100	35.6	34.5	22.6	20.2	0.6	1.3	0	2.66

At salinities of 2 and 1°/oo, the accretion was very insignificant, making up 1.3 to 1.9°/o of the growth in the control samples. The difference between the absolute magnitudes of accretion in the colonies of both of the series is, undoubtedly, determined by dissimilar conditions of feeding during the experiments.

Variations in the number of hydranths in the colonies of P. megas, which live at salinities of 8.5 and 3°/oo, are analogous to variations in the rate of growth of the colonies in a water having the same salinity.

As seen from Table 5, by the end of the observations, the increase in the number of hydranths and the length of stolons in the control samples was almost three times greater than in tests where the salinity of water was 5°/oo, and almost 51 times greater than in tests with water having a salinity of 3°/oo.

At salinities of 2 and 1°/oo, the colonies had as a rule one hydranth — i.e. 14 times less than in the control samples. The accretion of stolons in water having the salinity of 1°/oo was even greater than that in water having the salinity of 2°/oo; at the same time, the greatest death rate was observed here; of course, the greater accretion can be explained by the fact that the fittest colonies survived. An analysis of the data makes it possible to assert that the number of capita of hydranths varies with days, the same way as the length of stolons. Such data were obtained by Kinne (1956a) for cordylophores. Therefore, from now on, in cases when, for one or the other reason, it is almost impossible to measure the length of stolons, data on the variations of the number of capita of hydranths can be utilized as growth coefficients.

Thus, the ratio of accretion of stolons to the number of hydranths in P. megas colonies at decreased salinities appeared to be almost identical on the basis of both of the series of tests. The greatest magnitudes were gained in water having the salinity of the natural habitat of the species; with a decrease of water salinity to 5-3°/oo, the magnitudes decreased several times, but with a dilution to 1-2°/oo, no accretion was observed. On the basis of these data, it can be assumed that a small decrease of salinity (3-5°/oo), in comparison with the salinity of the natural habitat in the Zhdanov area, limits to a degree the growth rate of P. megas of the given population.

One may assume that a decrease of salinity to 5-3°/oo in natural conditions must limit the development of the species population, the mass accumulations of which develop, obviously, at salinities exceeding 5°/oo.

However, such a limitation of mass development of P. megas in diluted water does not exclude the possibility of a lengthy survival of individual colonies in almost pure water: in the case of the hydroid population that was investigated, 15°/o appeared to be able to survive for a month in water having a salinity of 1°/oo.

This peculiarity of P. megas played, undoubtedly, a great role in the propagation of the species, establishing settlements in a new water area — the Caspian Sea. The immigration of the hydroid into the Caspian Sea, which was noted during recent years (Zevina, Kuznetsova, Starostin, in this compilation of papers), occurred most probably via the Volga-Don river system, where the P. megas colonies lived in fresh water.

CONCLUSION

A new species of hydroids — P. megas — was found in the water supply system of a metallurgical plant on the coast of the Sea of Azov. The species is found in fouling throughout the year. Its maximum development is reached in June-July, whereby the biomass does not exceed 10 kg/m^2 at the time. With a decrease of water temperature to 10-9°C, a smaller amount of hydranths is reduced; and from October to Apr 1 it is found to be the least active form — in the stolon phase. The regeneration of polyps takes place at temperatures of 9-10°C. The settlement of larvae begins usually in spring when the temperature is above 15°C.

A decrease of salinity in comparison with the salinity of the natural habitat for the hydroids has created a decrease in the growth rate and the death of part of the colonies, whereby with the dilution of the water, the growth of colonies and the number of surviving animals have decreased. The dilution of water to 1‰ practically stopped the growth of P. megas so that 85% of the colonies perished. The survival of 15% of the colonies in almost completely diluted water attests to the nonuniformity of reaction by various colonies of the same populations of hydroids to the dilution of water. This nonuniformity of reaction has, evidently, contributed to the penetration of the species into the Caspian Sea via the Volga-Don Canal.

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L. A. Rosenberg

QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF BACTERIAL FOULING ON METAL PLATES

Abstract

The work was carried out in the Gelendzhikskaya bukhta of the Black Sea. Metallic plates of stainless and carbon steel and duralumin were submerged into the water for a period of one year and a half. Studies of the dynamics in the development of sulfate-reducing and saprophytic bacteria on the metallic surface showed that their great quantity underwent seasonal changes.

Many investigators have studied the microflora of the Black Sea. F. I. Kopp (1948, 1949) discovered that septic, sulfate-reducing, and denitrifying bacteria are found in the entire water layer of the Black Sea, from surface to bottom. The major part of the latter deoxidize nitrates to nitrites. The hydrogen sulfide of the Black Sea is formed mainly in the bottom layer as a result of the reduction of sulfate (Kriss and Rukina, 1949). The sulfate-reducing bacteria are, as a rule, found in bottom sediments, not in the water layers. They do not develop in the water layers. The upper layers of the sea (but in other seas and oceans often the entire water mass) are usually well aerated, creating unfavorable conditions for the development of anaerobic bacteria. These bacteria can propagate more or less widely only in the coastal belt of seas, in harbors and bays where industrial wastes, rich in organic substances, are deposited. If the amount of soluble organic matter is large in sea water during calm weather, the dissolved oxygen may disappear entirely as a result of biological oxidation. Thus, favorable conditions for the development of sulfate-reducing bacteria are created in surface waters. On the other hand, metallic plates submerged into sea water are covered by bacterial, plant, and animal foulings. Such a coating inhibits the flow of oxygen, and anaerobic conditions are created under the coating on the surface of the metal. Electrochemical corrosion of metals in sea water induces the creation of hydrogen molecules that settle on the cathode (Rosenberg, in this compilation of papers). Such a presence of sulfates (sulfides?), molecular hydrogen, and anaerobic conditions also create optimal prospects for the development of sulfate-reducing bacteria on metallic surfaces under the fouling.

In this study I want to demonstrate the dynamics of the development of sulfate-reducing and saprophytic bacteria on metal plates in Gelendzhikskaya bukhta of the Black Sea. For this purpose, the bacterial communities of fouling and the products of metal corrosion were repeatedly analyzed.

THE METHOD

A number of metallic plates (of rust proof steel IXI8H9T, of carbon steel Cт-3 and of duralumin Д-16) were placed on the stand of the Institute of Physical Chemistry of the Academy of Sciences of the USSR in Gelendzhikskaya bukhta in April 1960. The samples were removed in August (after 126 days) and in December (after 259 days) 1960; in April (after 375 days), in June (after 463 days), and in September (after 527 days) 1961. The frame with its plate was always raised to the surface. All the fouling with corrosion products was carefully scraped from a definite area of the plate and placed into a sterile test tube. The tube was covered by a sterile rubber cork and paraffinized. The sampled area of the plate was measured and the frame was returned to its previous place. With each subsequent sampling, a new area of the plate was utilized. In the analysis, 10 mℓ of sterile water was added to the sample. The tubes were carefully agitated; after the agitation, the needed solutions were made. /226

The following groups of bacteria were determined: sulfate-reducing — in agaraceous Tausson medium; sporogenic and asporogenic forms, as well as aerobic and anaerobic species of saprophytic bacteria — in a peptonic meat agar; actinomycetes — in a starch-ammonium agar; ammonifiers — in peptonic water;and denitrifiers — in the Giltay medium. All of the data were reduced to 1 cm^2 of the surface of the metal plates.

The sample taking was associated with the study of the character of fouling and corrosional damage to the metal plates.

This study was aided by the cooperation of I. B. Ulanovskiy and Yu. M. Korovin, who put the metal plates on their stands and placed them at my disposal afterwards; also R. D. Nikolayeva cooperated by taking samples from the plates according to my instructions.

DYNAMICS IN THE DEVELOPMENT OF SULFATE-REDUCING AND SAPROPHYTIC BACTERIA ON METALLIC PLATES

Corrosion centers in the form of pits and other local da ages were never observed on ie plates. All of the plates contained animal and plant fouling, the amount of which was smaller at the beginning and greater later. The basic elements of fouling were higher and lower algae, hydroids and bryozoans, less often mytilaceans and barnacles were encountered. The carbon steel and duralumin plates had developed abundant corrosion products under the fouling. The plates of stainless steel contained insignificant traces of corrosion.

The development of sulfate-reducing bacteria on three metal types was similar. The numbers presented in Fig. 1 attest to the abundance of sulfate-reducing bacteria in Gelendzhikskaya bukhta within a limited sea area, where the test plates had been submerged. The presence of favorable anaerobic conditions for sulfate-reducing bacteria is obvious. The water is enriched with organic substances of industrial and domestic wastes, as well as with decomposing plant and animal foulers. Even in the surface layer of water one may encounter anaerobic conditions. Therefore still more favorable anaerobic conditions are created under the fouling on metallic plates.

The development of saprophytic bacteria differs from the development of sulfate-reducing bacteria (Fig. 2). If the maximum numbers of sulfate-reducing bacteria pertain to July 1961, the maxima of saprophytic bacteria are displaced toward April 1961. However, the character of the curves characterizing the numbers of saprophytic bacteria for the three various metal plates have a rather similar form.

By the end of our observations (August-September 1961) the number of saprophytic bacteria decreased to a level slightly exceeding the number observed in August 1960, concluding the yearly cycle of development. /228 However, the quantity of sulfate-reducing bacteria also decreased, but by September 1961 the number remained rather high; in all probability, the minimum must be reached somewhat later.

In order to present a microbiological characterization of fouling on the metal plates, the relationship between the numbers of sporogenic and asporogenic forms of saprophytic bacteria is essential. S. I. Kuznetsov demonstrated that the quantitative relationship between the

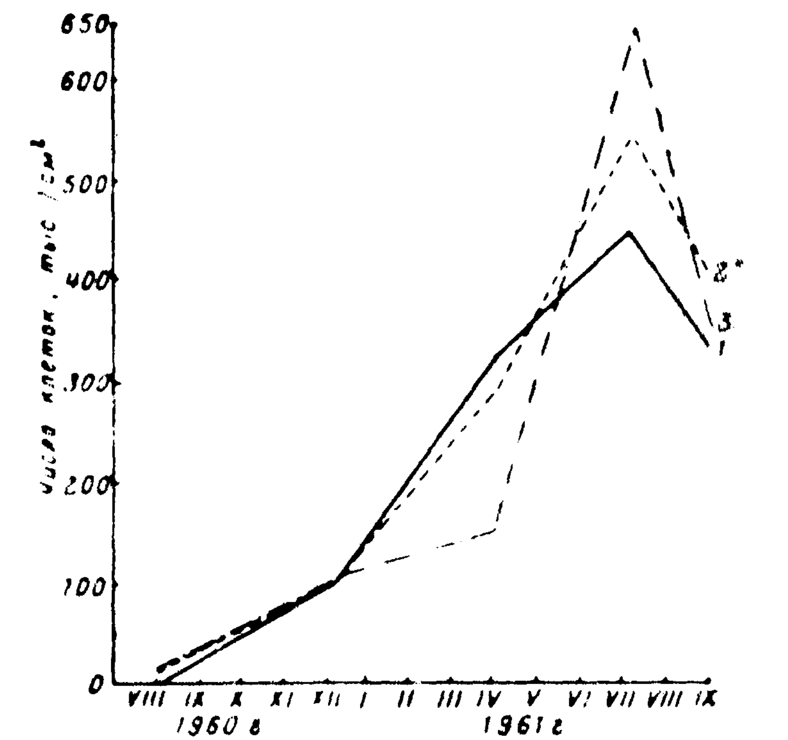

Fig. 1. Seasonal variations in the numbers (thousands of cells per 1 cm^2) of the sulfate -reducing bacteria on metallic plates.

1 — 1Х18Н9Т; 2 — Ст-3; 3 — Д-16.

x-axis: number of cells, thousands/cm^2
y-axis: months - 1960 — 1961

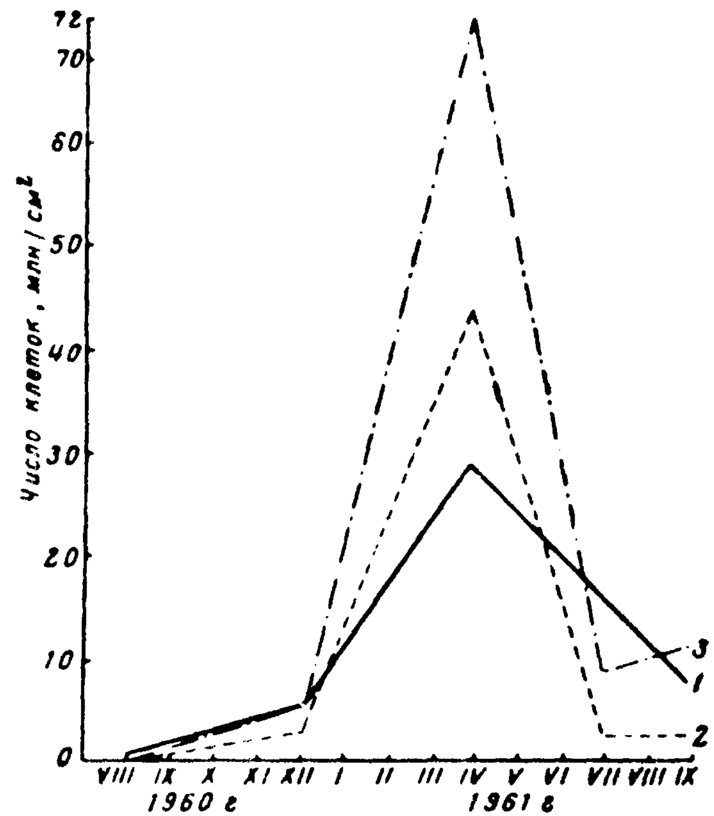

Fig. 2. Seasonal variations in the numbers (millions of cells per 1 cm^2) of saprophytic bacteria on metallic plates.

1 — 1Х18Н9Т; 2 — Ст-3; 3 — Д-16.

x-axis: number of cells, millions/cm^2
y-axis: months - 1960 — 1961

sporogenic and asporogenic forms of saprophytic bacteria is in harmony with the extent of the trophicity of lakes (Kuznetsov, 1952). The greatest number of asporogenic forms are found in eutrophic lakes; here the amount of sporogenic forms does not exceed 10°/o of the total number of saprophytic bacteria. In order to develop asporogenic forms of saprophytic bacteria in water, the part of the organic matter that can be readily utilized for this purpose, and not the entire organic matter that is dissolved in the water, is of great significance. A decrease in the concentration of organic matter that can be readily utilized, despite the large total amount of organic matter that is dissolved, increases the number of sporogenic forms of the saprophytic bacteria.

Table 1

Quantitative Relationship of Sporogenic and Asporogenic Forms of Saprophytic Bacteria
(thousands per 1 cm^2)

Period during which the samples were found in the sea, days	IX18H9T			Ст-3			Д-16		
	Total number of saprophytes	Number of sporogenic forms	Percentage of sporogenic forms of saprophytes	Total number of saprophytes	Number of sporogenic forms	Percentage of sporogenic forms of saprophytes	Total number of saprophytes	Number of sporogenic forms	Percentage of sporogenic forms of saprophytes
126	808	163	20.1	151	61	40.4	150	30	20.0
259	5,376	694	12.9	2,838	402	14.1	4,978	664	13.3
375	28,636	2,568	8.9	44,153	3,660	8.3	71,849	2,689	3.7
463	15,697	1,171	7.4	2,345	326	11.4	7,760	100	1.3
527	5,460	309	5.6	2,766	282	10.2	9,001	493	5.5

MICROBIOLOGICAL CHARACTERIZATION OF FOULING ON METALLIC PLATES

The data listed in Table 1 are of interest from this point of view. The data show that the water coming in touch with the plates in the Gelendzhikskaya bukhta in August and December 1960 was deficient in organic matter that could be utilized. The results of the microbiological analysis of samples, obtained on the first two dates, show that the number of sporogenic forms of saprophytic bacteria fluctuated from 12.2 to 40.4°/o. Later, the water was enriched by organic matter that could be readily utilized. This increased the quantity of asporogenic forms.

Table 2 characterizes to a certain degree the living conditions for the bacterial biocoenosis on metal plates under the marine fouling. It is seen from the table that the conditions created on the plates of carbon steel and duralumin are more anaerobic than on stainless steel. Evidently, this can explain a less intense development of sulfate-reducing bacteria on stainless steel.

Table 2 /229

Quantitative Relationship of Aerobic and Anaerobic Species of Saprophytic Bacteria (thousands per 1 cm^2)

Period during which the samples were found in the sea, days	1X18H9T			Ст-3			Д-16		
	Total number of saprophytes	Number of sporo-genic forms	Percentage of sporogenic forms of saprophytes	Total number of saprophytes	Number of sporo-genic forms	Percentage of sporogenic forms of saprophytes	Total number of saprophytes	Number of s[illegible]o-genic forms	Percentage of sporogenic forms of saprophytes
126	808	473	58.5	151	47	31.1	150	83	55.3
259	5,376	348	6.5	2,838	1,538	54.2	4,978	2,600	52.2
375	28,636	1,807	6.3	44,153	1,691	3.8	71,849	5,098	7.1
463	15,697	2,198	14.0	2,845	638	22.4	7,760	1,164	15.0
527	5,460	1,757	32.1	2,766	537	19.4	9,001	2,714	30.1

Table 3

Qualitative Characterization of Saprophytic Bacteria
(thousands per 1 cm^2)

Bacteria	Finding of samples in the sea, days				
	126	259	375	463	527
Steel IX18H9T					
Total number of saprophytes. . .	808	5,379	28,636	15,697	5,460
Including:					
actinomycetes.	9	146	1,318	131	97
ammonifiers.	79	658	11,364	12,074	950
denitrifiers	0.5	7.5	3.4	0.1	0.1
229 **Steel Cт-3**					
Total number of saprophytes. . .	151	2,838	44,153	2,845	2,766
Including:					
actinomycetes.	6	2	138	6	26
ammonifiers.	89	549	13,846	1,294	1,820
denitrifiers	0.3	0.1	15.4	0.3	0.2
Duralumin Д16					
Total number of saprophytes. . .	1,503	4,978	71,849	7,760	9,001
Including:					
actinomycetes.	1	6	70	24	45
ammonifiers.	47	664	12,605	2,686	2,741
denitrifiers	0.3	0.1	0.5	0.1	0.3

Nitrifiers were never found in samples among bacteria (Table 3). Denitrifiers were found in relatively small numbers. The denitrifying bacteria are, evidently, insubstantial in the bacterial biocoenosis on metal plates. In all probability, the water that comes in contact with the metal plates contains a small quantity of nitrates and therefore the denitrification processes are weak, even if the organic matter is available and the anaerobic conditions are favorable. Actinomycetes and ammonifiers, which are important for the mineralization of organic matter, occupy an important part among saprophytic forms. Actinomycetes and ammonifiers, as well as the general quantity of saprophytes, reached maximum numbers in April 1961.

CONCLUSIONS

The quantity of sulfate-reducing bacteria on metal plates is considerable. This shows that, in the area where the plates were placed, the conditions for sulfate-reducing bacteria were favorable; the water is enriched with organic matter as a result of domestic and industrial wastes in the water, and of the decomposition of plant and animal foulers; thus, in the water, which is rich in organic substances, anaerobic conditions are created on metal plates beneath the marine fouling.

The numerical values of saprophytic bacteria are high. Actinomycetes and ammonifiers play a significant role among the bacteria.

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THE DEPOLARIZING ROLE OF SOME OF THE SULFATE-REDUCING AND SAPROPHYTIC BACTERIA IN THE ELECTROCHEMICAL CORROSION OF STAINLESS AND CARBON STEEL

Abstract

Results of experiments with bacteria showing their depolarizing role in the electrochemical corrosion of steel exposed to sea water are given.

The preceding studies of mine, that had been carried out jointly with physicists-chemists I. B. Ulanovskiy and Yu. M. Korovin (Rosenberg, Ulanovskiy, Korovin, 1959; Rosenberg, Ulanovskiy, 1960; Ulanovskiy, Rosenberg, Korovin, 1960; Rosenberg, Korovin, Ulanovskiy, 1961), established that bacteria, by growing directly on the passive surface film of metals, diminish their protective qualities by displacing the electrode potential to the negative side, by which they further the appearance of microgalvanic couples.

The effect of bacteria on the corrosion of iron and carbon steel in sea water is discussed in studies by Kanygin, 1937; Reynfel'd, 1939, 1941, 1942; Hadley, 1939, 1940; Thomas, 1942; Rogers, 1945; Hill, 1946; Nikitina, Ulanovskiy, 1954, 1957; Ulanovskiy, Nikitina, 1956; Kuznetsov. 1958; Gasanov, 1961; and Rosenberg, 1961. However, the major part of the studies discuss the effect of sulfate-reducing bacteria on the corrosion of the metals; whereas the processes of biocorrosion caused by ammonifiers, denitrifiers, iron bacteria, and others have hardly been investigated.

As a result of the activity of bacteria, the corrosion of metals in sea water intensifies because the passive protective resistance of the film of carbonic acid — which is a product of the final oxidation of organic matter by bacteria — is neutralized and the cathode of the metal with respect to hydrogen is depolarized. Inasmuch as the physical-chemical effect of a number of bacteria on stainless steel has already been established, the problem of this investigation lies in studying the role of sulfate-reducing and saprophytic bacteria in the corrosion of stainless and of carbon steel in sea water. For this purpose special laboratory tests were made, elucidating the effect of Vibrio desulfuricans on the corrosion of stainless steel IX18H9T and on carbon steel Cт-3, as well as the effect on the corrosion of steel

Cт-3 of the following saprophytic bacteria: Bacillus mycoides Flugge, Bac. tenuissimus n. sp., Bac. aridus Migula, Bac. subtilis Cohn, Bac. nitidus Bredemann et Heigener, Bac. megatherium De Bary, Bac. lividus voges, Bac. agile Jensen, Pseudomonas fluorescens Migula, Pseudobacterium subluteum (Dobrr.) n. comb., Chromobacterium tremeloides (Tils), Micrococcus albicans Trevisan, Microc. sphaeroides Gray et Thornton, Streptococcus mesenterioides Migula, Sarcina citrina Gruber.

The above samples were collected by separating individual microbes from bacterial settlements on the metal plates, that had been kindly submerged in water by I. B. Ulanovskiy and Yu. M. Korovin at the corrosion station of the Institute of Physical Chemistry of the Academy of Sciences of the USSR in the Gelendzhik area. The samples were taken from the metal plates in accordance with instructions by R. D. Nikolayeva, laboratorian at the Black Sea Experimental Station of the Institute of Oceanology of the Academy of Sciences of the USSR. I express my most sincere gratitude to the above mentioned comrades.

THE METHOD

The cultures of V. desulfuricans were kept in anaerobic conditions in artificial sea water with an addition of sodium formate and in a liquid Tausson medium composed of (in grams) tap water - 1000.0; ammonium sulfate -4.0; potassium phosphate, dibasic - 0.5; calcium sulfate - 0.5; magnesium sulfate - 1.0; sodium formate - 3.5.

The filling of containers with the liquid medium, their sterilization, the preparation and weighing of the steel plates was carried out in the same way as described above (Rosenberg, 1961).

Each container was inoculated with 3 $m\ell$ of a ten-day V. desulfuricans culture in the Tausson medium, and all of the containers were placed in an incubator at 25-27°C.

The cultivation of saprophytic bacteria was done in the same way as that of V. desulfuricans in the liquid media, but in anaerobic conditions. A thin layer of liquid was poured into the containers so that the steel plates Cт-3 suspended on caprone cords were completely submerged, and then the containers were closed by cotton plugs.

The tests with the cultures of saprophytic bacteria were conducted in artifical sea water (Rosenberg, 1961), to which 0.05°/o of peptone was added in lieu of sodium formate, which was used in tests with Vibrio desulfuricans. In addition, tests with Ps. fluorescens and Bac. mycoides were also conducted in peptonic water: tap water - 1000.0; peptone - 5.0; potassium phosphate, dibasic - 1.0; magnesium sulfate - 0.5; sodium chloride - 0.1.

The media were inoculated with saprophytic bacteria so that each 100 mℓ of liquid contained 0.25 mℓ of aqueous mixture with two-day old agaric cultures.

When the observations on the corrosional effect of bacteria were carried out, no iron was added to the liquid on the assumption that a certain quantity of iron will infiltrate the liquid from the metal plates.

In tests with iron sulfide, 1 mℓ of 5% Mohr's salt solution and 3 mℓ of 10% sodium sulfide dissolved in 5% soda were added to each 100 mℓ of liquid medium.

The plates of stainless steel IX18H9T that were used in the tests had the form of squares, the working surface of which was about 15 cm^2; whereas the plates of carbon steel Cт-3 used in the tests had a rectangular form, the working surface being about 10 cm^2.

Only the bacteria that had been developing on the surface of the steel plates were accounted for in the analyses. For this purpose, all the fouling was scraped off together with the products of corrosion. The material was put into a test tube containing 10 mℓ of water; afterwards the needed dilutions and cultivations were prepared. In order to account for the V. desulfuricans, the cultivations were made in agaraceous Tausson medium. The colonies of bacteria were counted after 20 to 24 days. The saprophytic bacteria were calculated by culturing with peptonic meat agar (MPA), and the mature colonies of the bacteria were counted after two to three days.

In contrast to my earlier investigations, where only the microscopic method was used for the calculation of V. desulfuricans, I utilized here the cultivation method because it was important to have an idea on the quantity of live and active organisms. Besides, one should take into consideration the deficiencies of the microscopic method (Kalinenko, 1953; Rosenberg, 1954). /233

After the fouling had been scraped off the surface of metal, the material was carefully cleaned from the residues of corrosion products by means of a special paste (Patrikeyev and Arbuzova, 1962). The metal plates were then treated with alcohol, dried in the air, and weighed. The weight losses during the test were calculated by the formula:

$$\frac{(Б - В) \cdot 10\ 000}{A}\ g/m^2,$$

where — B denotes losses (in g) during the test; 10 000 is the coefficient for conversion of cm^2 (into m^2); and A is the total working surface of the sample (in cm^2).

The hydrogen sulfide was determined in the medium by the iodometric method, but ammonia was determined colorimetrically with the aid of the ФЭК-M (Photoelectronic colorimeter by Munsell) colorimeter using the Nessler solutions.

THE FORMATION OF HYDROGEN SULFIDE IN CONNECTION WITH THE ACTIVITY OF V. DESULFURICANS CULTURES

As demonstrated by a number of authors (Sisler, ZoBell, 1950, 1951; Sorokin, 1954, et al), this organism can reduce sulfates by utilizing molecular hydrogen as the source of energy. Therefore the sulfate-reducing bacteria are capable of acting as cathode depolarizers in anaerobic conditions by utilizing the liberated hydrogen, the accumulation of which on the cathode has created the polarization of microgalvanic elements of steel plates in sea water.

In order to investigate the activity of V. desulfuricans, 30 day tests with the cultures of the bacteria were set up in test tubes containing the liquid Tausson medium and artificial sea water without introducing the steel plates, but using instead iron in the form of Mohr's salt.

It is seen from Table 1 that the development of bacteria in the Tausson medium and in sea water occurs at the same rate of intensity within the first five days. Whereas the formation of hydrogen sulfide in the Tausson medium is twice as intense during the same time, than in sea water. Beginning with the seventh day, the reproduction of bacteria and the increase in the hydrogen sulfide concentration occurs more or less

Table 1

Intensity of Hydrogen Sulfide Formation in a Medium Depending Upon the Activity of Bacterial Cultures

	Days						
	2	5	7	10	15	20	30
Tausson Medium							
Bacteria, thous/mℓ of medium.	49.9	57.9	394.4	434.5	1240.0	1490.0	2000.0
H_2S, mg/ℓ	19.3	53.9	195.0	223.1	247.2	306.4	368.5
Artificial Sea Water							
Bacteria, thous/mℓ of medium.	33.1	45.6	45.6	50.3	131.0	191.5	192.0
H_2S, mg/ℓ	22.1	23.7	24.4	25.4	42.6	43.8	43.6

smoothly in sea water. Beginning with the 15th day, a sharp increase /234 in the number of bacteria is noticeable. The reproduction of cells and the formation of hydrogen sulfide in the Tausson medium occurred during the entire test period, while in sea water these processes ceased on the 20th day of the experiment.

It was shown before that the development of V. desulfuricans on stainless steel plates sharply displaces the electrode potential toward the negative side (Ulanovskiy, Rosenberg, Korovin, 1960), creating favorable conditions for the formation of galvanic couples, which, in turn, lead to the corrosion and destruction of metal (Rosenberg, Korovin, Ulanovskiy, 1961). The data listed in Table 2 demonstrate convincingly that biocorrosion begins to appear after the creation of galvanic couples on the surface of stainless steel that has been infected with sulfate-reducing bacteria. The biocorrosional damage of metal becomes clearly pronounced when the effect of the cultures of sulfate-reducing bacteria on the stainless steel plates is continual, despite the fact that unfavorable conditions for the reproduction of bacteria are created at the time.

Table 2

The Effect of *V. desulfuricans* on the Corrosion of Steel 1X18H9T

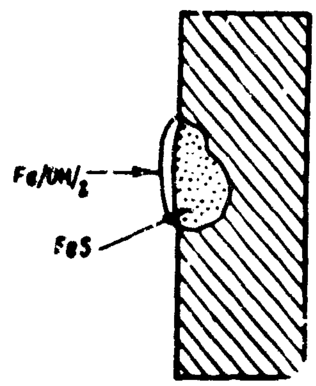
Test	Duration of test, days	Tausson Medium			Artificial Sea Water		
		bacteria, thous /cm^2	H_2S, mg/ℓ	weight loss, g/m^2	bacteria, thous /cm^2	H_2S, mg/ℓ	weight loss, g/m^2
Medium without bacteria, control conditions							
Without adding iron to the medium	30	—	0.0	0.014	—	0.0	0.008
	435	—	0.0	0.092	—	0.0	0.060
Adding FeS	30	—	0.0	0.012	—	0.0	0.00[illegible]
	435	—	0.0	0.073	—	0.0	0.10[illegible]
Medium, infected with bacteria							
Without adding iron to the medium	5	19.9	—	—	6.7	—	—
	10	31.1	—	—	10.3	—	—
	30	54.0	130.9	0.074	44.2	38.5	0.048
	154	35.9	192.2	0.110	24.1	38.1	0.081
	435	15.6	209.3	0.200*	4.7	31.2	0.135
Adding FeS	5	27.6	—	—	—	—	—
	10	50.3	—	—	—	—	—
	30	122.2	200.9	0.090	50.3	61.8	0.104
	154	8[illegible].8	288.9	0.150	36.9	39.1	0.132
	435	25.2	230.6	0.910**	7.3	32.8	0.153

*One of the steel plates showed that the weight loss was 12.8 g/m^2.

**One of the steel plates showed that the weight loss was 126.1 g/m^2 (see also the figure).

It is seen from Table 2 that the reproduction of cells of *V. desulfuricans* on the surface of stainless steel and the formation of hydrogen sulfide by them in the media are completed in 150 days. An earlier study by Rosenberg (1961) remarked that a further reproduction of *V. desulfuricans* and the creation of hydrogen sulfide ceases in about 12[illegible] days. L. I. Rubenchik (1950) notes that the cessation of reproduction of V. desulfuricans and of the reduction process of sulfates in the medium, the composition of which is similar to the Tausson medium, aided by iron and steel wires (made in all probability of carbon steel) sets in by the end of the first month.

In the tests the number of bacteria began to decrease in 150 days, reaching in 435 days the magnitude that had been observed in the first days of the experiment. The formation of hydrogen sulfide ceased, but its concentration remained on the former level as in the case with the flasks, remaining hermetically closed. Such a decrease in the number of bacteria could be explained by the impoverishment of nutrients within the medium, by the accumulation of metabolic products, and by the beginning of autolysis of the cultures.



A diagram of local corrosional damage on a lateral face of stainless steel sample IX18H9T.

It is seen from Table 2 that in the Tausson medium the conditions for the reproduction of bacteria and for the formation of hydrogen sulfide were more favorable than in the sea.

The sulfate-reducing bacteria, by developing on steel samples in sea water containing organic substances, form hydrogen sulfide from sulfates and, in addition, they act as depolarizers, oxidizing the molecular hydrogen on the cathode. Hydrogen sulfide, on the other hand, furthers the formation of FeS, which, coming in contact with iron, intensifies corrosion. This problem has also been mentioned in papers (Krotov, 1939; Kuhr, 1934). Earlier (Rosenberg, 1961) it was established that, despite the intense development of V. desulfuricans and a relatively intense formation of hydrogen sulfide by the cultures on the surface of stainless steel, the metal is subjected to very insignificant corrosion. On this basis, I attempted to intensify the corrosion of stainless steel in active cultures by adding FeS. As is seen (Table 2), the adding of iron sulfide to the cultures increase the number of bacteria, both in tests with the Tausson medium and in tests with artificial sea water. The adding of iron sulfide also increases the concentration of hydrogen sulfide in the medium surrounding the samples.

Intense corrosion of IX18H9T samples was observed in the Tausson medium (comp. weight losses in control samples of both media, which were not treated with bacteria; Table 2). The corrosion is more intense in samples that have been exposed to bacteria. The experiments demonstrate that the corrosion of stainless steel IX18H9T is noticeable in 30 days. If the experiments last longer (more than 150 days) — and conditions for the development of V. desulfuricans become more unfavorable — the depolarization of microcathodes is, evidently, intensified and the phenomenon of biocorrosion in stainless steel becomes more pronounced. The corrosional damage of steel samples became more evident after the samples had been exposed to bacteria for 435 days, and when the weight loss of samples reached 0.2—0.9 g/m^2.

The tests are also convincing for the reason that the introduction of iron sulfide into the cultures intensifies the biocorrosion of the steel sample IX18H9T. It is obvious that the introduction of iron sulfide into the control tests without bacteria does not intensify the corrosion of samples. Hydrogen sulfide is entirely absent in the control tests. The iron sulfide, which was also introduced in the control flasks when the tests were set up, oxidizes rather rapidly, forming Fe_2O_3 and $Fe(OH)_2$. The blackening of the medium, which sets in right after the introduction of iron sulfide into the flask, disappears completely in two to three days, so that only a brownish sediment typical of the hydrate of ferric nitrate is seen.

The notes to Table 2 show exceptionally great weight losses in the bacterial samples kept in the Tausson medium. These samples were investigated separately from the others, and their data were not listed in the table. The first sample had a deep graphite damage on the lateral face, the corrosion products of which consisted mainly of FeS. The second sample also had a damaged lateral face. A brownish condensation ($Fe(OH)_2$) was seen on it under which a deep recess filled with black graphite corrosion products, representing FeS, was noticeable (see the diagram). Although it was impossible to establish the causes for such deep and exceptional corrosional damages in the stainless steel, these rarely seen facts have to be mentioned because they indicate that the biocorrosion of stainless steel can be very intense when the steel comes in close contact with iron sulfide and when the active cultures of V. desulfuricans are present. /236

THE INFLUENCE OF V. DESULFURICANS ON THE CORROSION OF CARBON STEEL

The tests were conducted during 30 to 40 days. It was impossible to continue the testing because the attack by sea water caused intense corrosion in the samples of carbon steel, due to which the corrosion products from the surface of the steel samples were rather readily falling on the bottom of the flask. Not infrequently one could observe weight losses reaching 60–70 g/m^2 in 30 to 40 days in the sterile flasks.

Also the attack by the Tausson medium as regards the carbon steel was rather intense, though it lagged behind the attack of sea water. As seen from Table 3, the weight loss in the sterile flasks containing the Tausson medium was half as much as the loss observed in similar conditions in sea water, reaching 20 g/m^2 in 40 days.

Inasmuch as the attack by sea water and the Tausson medium caused considerable corrosional damages in steel Cт-3 samples in tests without bacteria, an attempt was made to exclude the corrosion of samples as a result of the attack by the liquid medium, so that the extent of biocorrosion caused by the activity of bacteria could be determined. For this purpose, the rate of corrosion of the samples (g/m^2/hour) was expressed in percentages of the rate of corrosion in the control samples. Such calculations were also made in tests with saprophytic bac-
16 teria.

The great activity of sea water created a more intense corrosion in samples which were placed in sea water containing cultures of sulfate-reducing bacteria; the effect of the Tausson medium was less pronounced (Table 3), despite the fact that in the Tausson medium the development of bacteria is more intense on the surface of samples and the concentration of hydrogen sulfide is greater.

The abundant corrosion products on the samples of carbon steel, which are formed both in the Tausson medium and in sea water, are readily washed off and sink to the bottom of the flask. Therefore a great care is required when working with the test flasks, because considerable losses in corrosion products have to be avoided. And yet, despite all the care, part of the corrosion products are washed off the samples. Therefore the investigation of fouling yields a diminished number of bacteria.

Table 3

The Effect of V. desulfuricans on the Corrosion of Steel
Cт-3 Samples

Medium	Duration of test, days	Control			Medium, infected with bacteria				
		Weight loss of sample, g/m^2	Rate of corrosion, $g/m^2/hour$	%	Bacteria, thous/cm^2	mg/l	Weight loss, g/m^2	Rate of corrosion, $g/m^2/hour$	%
Tausson without iron	10	9.7	0.040417	100.0	31.4	197.1	9.8	0.040833	101.0
	20	—	—	—	35.4	195.8	10.9	—	—
	30	—	—	—	354.1	301.4	10.8	—	—
	40	18.8	0.019583	100.0	352.1	314.6	18.6	0.019375	98.9
Sea water without iron	10	9.2	0.038333	100.0	10.3	15.2	10.4	0.043333	113.0
	20	—	—	—	26.6	21.7	20.8	—	—
	30	—	—	—	33.8	20.1	31.3	—	—
	40	40.7	0.042395	100.0	34.7	20.1	48.5	0.050521	119.2
Tausson with iron	10	10.1	0.042083	100.0	50.3	291.7	10.8	0.045000	106.9
	20	—	—	—	53.1	247.2	20.5	—	—
	30	—	—	—	219.8	251.0	20.8	—	—
	40	19.7	0.020521	100.0	257.0	247.3	26.4	0.027500	134.1
Sea water with iron	10	9.4	0.039166	100.0	1.0	15.2	10.6	0.043333	110.7
	20	—	—	—	5.2	18.5	20.4	—	—
	30	—	—	—	9.7	15.0	41.3	—	—
	40	40.4	0.042083	100.0	14.5	18.2	55.2	0.057500	136.6

Theoretically it can be assumed that the surface of carbon steel samples, owing to the impressive corrosion products, is more favorable for the development of V. desulfuricans. The Cт-3 samples are covered by such an amount of corrosion products that the total surface, which can be infected by bacterial cells, increases considerably. Besides, the anaerobiosis, which is so important for the sulfate-reducing bacteria, increases under the corrosion products.

Despite all the precautions, the partial losses of corrosion products of the Cт-3 steel samples, which result from the removal of the flasks, make the calculation of bacteria incomplete. However, these losses do not affect the accuracy of determining the magnitude of the corrosion samples. Therefore the calculations of losses resulting from the corrosion of metal, and obtained by weighing the samples on analytical balances, are sufficiently dependable.

It is seen from Table 3 that the bacteria, that grow on Cт-3 samples in the Tausson medium without the addition of iron sulfide, do not create biocorrosion in the samples. The adding of sulfide furthers biocorrosion. The rate of corrosion increases after 40 days in such cultures by 34.1°/o in comparison with control samples. The tests conducted in sea water disclose corrosion with or without adding FeS. The corrosion rate in sea water is slightly greater than in the Tausson medium.

Consequently, iron sulfide furthers the increase of biocorrosion in the Tausson medium and in sea water. The Cт-3 steel corrosion does not occur in the Tausson medium without the addition of iron sulfide.

THE EFFECT OF SAPROPHYTIC BACTERIA ON THE CORROSION OF CARBON STEEL /238

The activity of saprophytic bacteria associated with the electrochemical corrosion of steel is subjected to the same regularities as the activity of sulfate-reducing bacteria. For some of them (Ps. fluorescens and Bac. mycoides) it was established that, as a result of their activity, the electrode potential of steel is displaced toward the negative side, which attests to the elimination of the passive surface film of steel (Ulanovskiy, Rosenberg, Korovin, 1960; Rosenberg, Korovin, Ulanovskiy, 1961). The same displacements of the electrode potential may result from the activity of other saprophytic bacteria.

The gas exchange in aerobic saprophytic bacteria is reduced to the absorption of oxygen from the surrounding medium and the liberation of carbonic acid. In addition, the saprophytic bacteria depolarize the cathodes of microcouples by deaminating peptone, form ammonia and organic acids, which are completely oxidised in aerobic conditions that are associated with the formation of carbonic acid. Thus, the corrosion of steel created by bacterial depolarization of the cathodes of microcouples is also sustained in the cultures of saprophytic bacteria. The carbonic acid accumulating as a result of the activity of saprophytic bacteria (gas exchange and oxidation of organic acids) upsets the protective characteristics of the passive film of steel, displaces the electrode potential toward the negative side, and sustains the work of galvanic couples. The ammonia formed by bacteria appears to be a corrosional agent, which, acting upon iron, creates the products of corrosion in the form of hydrates of the ferric oxide.

THE EFFECT OF PS. FLUORESCENS AND BAC. MYCOIDES ON THE CORROSION OF CARBON STEEL

It is seen from Table 4 that the development of bacteria is intense on the surface of samples and they form with great energy ammonia in sea water, to which peptone has been added. The reproduction of the bacteria and the formation of ammonia in tests conducted in peptonic water were more intense.

The cells of Bac. mycoides form colonies in the form of slimy filaments, which can, with a certain effort, be readily scraped off the surface of the sample. The stirring of the filaments in a test tube with water cannot divide them into individual cells. Therefore the materials of the solutions of samples scraped off the steel do not enable us to calculate accurately the number of bacteria. If, however, one takes into consideration the fact that it is impossible to avoid losses of corrosion products when removing the arranged flasks, it is natural that the obtained figures are always smaller than the actual number of bacteria. Therefore the data listed in Table 4 with respect to the numbers of Bac. mycoides are below the actual numerical values. Meanwhile, this microbe forms a greater quantity of ammonia nitrogen than does Ps. fluorescens. High ammonia concentrations are especially noticeable when the microbes are cultivated in peptonic water.

The biocorrosion of steel samples in sea water is rather considerable. Despite the fact that the attack by the sea water creates considerable weight losses in sterile samples (as many as 30 g/m^2 in 30 days), the corrosion rate in the cultures of bacteria after 30 days is twice as much as in the control flasks.

It is seen from Table 4 that by the end of the test the attack by sea water with respect to the samples of carbon steel is three times smaller than in sea water (sic!) ccultures in peptonic waters. The tests designed to establish the effect of Ps. fluorescens and Bac. mycoides on corrosion of Cт-3 in cultures with peptonic water demonstrated a considerably smaller intensity of biocorrosion in the steel samples, despite the fact that in this case the development of bacteria and the formation of ammonia was many times more intense than in tests with sea water. A sharp decrease in the biocorrosion of carbon steel, submerged into the cultures of bacteria with peptonic water, made us conduct tests aimed at the elucidation of the role of peptone in such experiments.

Table 4

Corrosion of Cт-3 Samples in Sea and Peptonic Waters

Medium	Duration of test, days	Without bacteria			With bacteria				
		Weight loss, g/m²	Corrosion rate, g/m²/hour	%	Bacteria, thous/cm³	N/NH₄, mg/ℓ	Weight loss, g/m²	Corrosion rate, g/m²/hour	%
		Test with Ps. fluorescens							
Sea water	5	10.6	0.08833	100.0	75.3	58.3	12.2	0.10166	115.1
	15	—	—	—	420.6	79.4	44.9	—	—
	30	29.6	0.04111	100.0	532.1	93.1	62.8	0.08722	212.1
Peptonic water	5	10.2	0.08500	100.0	117.3	69.7	10.4	0.08666	102.0
	15	—	—	—	2064.4	106.5	13.8	—	—
	30	10.5	0.01459	100.0	5621.0	113.9	15.6	0.02166	148.4
		Test with Bac. mycoides							
Sea water	5	10.8	0.09000	100.0	20.0	55.2	13.4	0.11166	124.1
	15	—	—	—	163.7	89.2	49.3	—	—
	30	30.1	0.04180	100.0	215.8	101.3	63.2	0.08777	209.9
Peptonic water	5	10.0	0.08333	100.0	24.5	330.4	10.4	0.08666	104.0
	15	—	—	—	215.6	455.5	12.1	—	—
	30	10.4	0.01444	100.0	1215.6	543.4	15.8	0.02194	151.9

THE EFFECT OF A NUMBER OF OTHER SAPROPHYTIC BACTERIA ON THE CORROSION OF CARBON STEEL IN SEA WATER

Insofar as observations on the biocorrosion of Cт-3 samples in the cultures of Ps. fluorescens and Bac. mycoides have demonstrated that this type of corrosion sharply decreases in tests conducted in peptonic water, the experiments with other saprophytic bacteria had been conducted only in sea water.

The development of saprophytic bacteria in sea water is dissimilar. Most of the species yield a high quantity of cells on the samples and lead to an intense ammonification of the medium, creating a pronounced corrosion in the samples. The corrosion rate in samples cultured with bacteria was 1.5 — 2.5 times greater than in the control samples when the cultures were 15 days old. This is clearly seen in the cultures of such bacteria as Bac. nitidus, Bac. agile, Micrococ. albicans, Micrococ. sphaeroides, and Sarcina citrina (Table 5), as well as in Ps. fluorescens and Bac. mycoides (Table 4). Bac. subtilis becomes active only by the end of the tests. This is seen by a successful development of cells and intensive formation of ammonia. In the second half of the tests the number of the bacteria on the surface of the plates increased 1.5 times. Despite this, the biocorrosion of the steel was insignificant, appearing only after a lengthy stay of the samples in the cultures of the bacteria. In all probability, this can be explained by a high rate of corrosion caused by sea water and by the character of bacterial fouling on the samples. The microbe forms a continual airtight film, which adheres to the samples. Not infrequently, greater /240 efforts were needed for the removal of the cultures from the steel samples. Such an airtight bacterial fouling decreases the contact of the latter with the medium and inhibits the effect of microcouples. However, a high attack by the sea water creates by itself intense corrosion in the samples not infected with bacteria, in comparison with which the quotients of biocorrosion were calculated.

Chromobacterium tremeloides and Bac. lividus stand out among the well developed bacteria on carbon steel samples. At the beginning, the former microbe creates insignificant corrosion in the samples, which later increases slightly, of course, despite the multitude of bacteria and the intense ammonification of the medium. It was impossible to find the cause for this. The absence of a noticeable corrosion in the samples with Bac. lividus is readily explained by the accumulation of insignificant quantities of ammonia in the medium, despite the intense reproduction of the microbe on the surface of the samples.

Table 5

The Effect of Saprophytes on the Cт-3 Corrosion in Sea Water

Culture	Duration of test, days	Without bacteria: weight loss in samples, g/m^2	Without bacteria: corrosion rate, %	With bacteria: bacteria, thous/cm^2	With bacteria: weight loss in samples, g/m^2	With bacteria: corrosion rate, %
Bac. nitidus	15	11.2	100.0	416.7	21.3	190.1
	33	64.0	100.0	143.5	69.0	107.8
Bact. agile	15	11.2	100.0	1041.6	21.5	191.9
	33	60.0	100.0	402.0	61.0	101.7
Micrococcus albicans	15	11.2	100.0	210.1	31.3	279.4
	33	63.0	100.0	264.5	64.7	102.7
M. sphaeroides	15	20.3	100.0	303.0	40.4	199.0
	30	59.9	100.0	115.2	40.0	66.8
Sarcina citrina	15	19.9	100.0	363.8	31.1	156.3
	30	52.6	100.0	367.7	53.4	101.5
Bac. subtilis	16	30.9	100.0	1071.4	31.0	100.3
	38	61.5	100.0	1449.1	70.4	114.5
Chromobacterium tremeloides	16	30.9	100.0	701.2	32.8	106.1
	38	74.5	100.0	680.6	82.2	110.3
Bac. lividus	15	19.9	100.0	917.0	20.1	101.0
	30	52.6	100.0	361.9	41.8	79.5
Bac. megatherium	15	28.8	100.0	1351.3	30.0	104.2
	30	52.6	100.0	707.8	49.5	94.1
Bac. tenuissimus	10	20.9	100.0	9.0	21.7	103.8
	20	42.6	100.0	26.5	51.3	120.4
	30	61.9	100.0	94.2	73.1	118.1
Bac. aridus	15	28.6	100.0	20.0	23.6	100.0
	30	42.7	100.0	101.5	49.3	115.0
Pseudobacterium subluteum	15	19.9	100.0	29.1	21.6	108.5
	30	52.6	100.0	21.0	59.7	113.5
Streptococcus mesenterioides	16	30.9	100.0	22.2	31.9	103.2
	38	74.5	100.0	45.1	70.7	94.9

<u>Bac. megatherium</u> has a somewhat different influence on the corrosion of Cr-3. As seen from Table 5, a luxurious development of bacteria accompanied with intense ammonification of the medium increases the corrosion of samples by 4.2°/o in 15 days. Further, the main factor of corrosion becomes the attack by the sea water, while the bacterial accumulations on the samples create a peculiar protective film. Such an early and intense corrosion agrees entirely with the data published before (Rosenberg, Ulanovskiy, 1960).

Table 6

Intensification of Corrosion of Cr-3 Samples With the Introduction of Iron Sulfide Into SeaWater at the Beginning of the Test

Culture	Duration of test, days	Corrosion rate, °/o of control samples	
		without FeS	with FeS
V. desulfuricans in the Tausson medium	10	101.0	106.9
	40	98.9	134.1
V. desulfuricans in artificial sea water	10	113.0	110.7
	40	119.2	136.6
Bac. tenuissimus	10	103.8	268.8
	20	120.4	102.5
	30	118.1	112.0
Bac. aridus	15	100.0	101.0
	30	115.0	137.9
Bac. subtilis	16	100.3	116.7
	38	114.5	120.8
Bac. nitidus	15	190.1	180.0
	33	107.8	121.7
Bact. agile	15	191.9	213.3
	33	101.7	121.2
Micrococcus albicans	15	279.4	112.4
	33	102.7	123.2

Such cultures as Bac. tenuissimus, Bac. aridus, Pseudobacterium subluteum, and Streptococcus mesenterioides developed weakly in the tests. As seen from Table 5, even a small number of Bac. tenuissimus and Bac. aridus caused biocorrosion in the samples, the rate of which was constantly increasing. Obviously, the numbers of bacteria increased by two-fifths on the steel samples and a considerable quantity of ammonia accumulated in the medium.

In a number of the tests, aimed at studying the effect of saprophytic bacteria on the corrosion of carbon steel, we added iron sulfide to the medium. This made it possible to elucidate the effect of iron sulfide, which intensifies the corrosional process, only on six bacterial cultures.

As seen from Table 6, the addition of iron sulfide to the medium accelerates the corrosion caused by Bac. tenuissimus only during the first 10 days, but the corrosion caused by Bac. nitidus and Micrococcus albicans is accelerated only by the end of the test, while the corrosion caused by Bac. aridus, Bac. subtilis, and Bact. agile is accelerated during the entire test period. It is also seen from Table 6 that the addition of iron sulfide to the cultures of V. desulfuricans stimulates the corrosion of Cт-3 during the entire test period, the corrosion being especially intense after 40 days.

ANTICORROSIONAL CHARACTERISTICS OF PEPTONE /242

It was pointed out above that a sharp decrease of biocorrosion results from the activity of certain saprophytic bacteria in cultures kept in peptonic water. We are inclined to consider it as anticorrosional characteristics manifest in peptone when kept in colloidal solutions. Evidently, peptone, when kept in the solution, forms a protective film of colloidal molecules on the surface of Cт-3 samples. This film acts like a calcareous film that settles electrochemically when the steel in sea water is subjected to cathodical protection (Ulanovskiy, 1956; Rosenberg, Ulanovskiy, 1960).

Special tests make it possible to establish anticorrosional characteristics of peptone. A series of flasks with sea water was used for such experiments; in some of the flasks peptonic water was added. Samples of Cт-3 steel were submerged in the flasks. The experiments were conducted in sterile conditions, and the flasks were kept 10 days in the incubator at 25-27° C. At the end of the experiments, the samples were taken out of the flasks and the weight loss of the samples was determined after the corrosion products were removed from the surface of the samples.

It is seen from Table 7 that, with an increase in the concentration of peptone, the corrosional influence of the medium on the carbon steel kept in sterile conditions decreases. In bacterial cultures, the corrosion of steel occurs somewhat differently.

Table 7

Anticorrosional Characteristics of Peptone
(the duration of tests was 10 days)

Medium	Peptone content in the medium, °/o	Weight loss in samples, g/m^2	Corrosion rate	
			g/m^2/hour	°/o
Artificial sea water without peptone.	0.0	53.2	0.22166	100.0
+0.5°/o of peptonic water. . . .	0.0025	40.7	0.16958	76.5
+1.0°/o " " "	0.005	22.2	0.09250	41.7
+1.5°/o " " "	0.0075	21.3	0.08875	40.0
+2.0°/o " " "	0.01	20.7	0.08625	38.9
Artificial sea water in cultures:				
sterile.	0.05	18.2	0.07583	34.2
with *Ps. fluorescens*	—	19.8	0.08250	37.2
with *Bac. mycoides*	—	21.9	0.09125	41.2
Peptonic water in cultures:				
sterile.	0.05	10.2	0.04250	19.1
with *Ps. fluorescens*	—	12.2	0.05166	23.3
with *Bac. mycoides*	—	12.6	0.05250	23.7

The development of *Ps. fluorescens* and *Bac. mycoides* cultures on samples causes increased corrosion of the metal. Bacteria, developing on the samples, destroy the colloidal peptonic film, deammonizing the peptone, so that the corrosion of metal is intensified. However, the activity of bacteria in the peptonic media cannot entirely eliminate the anticorrosional characteristics of peptonic films.

DISCUSSION OF RESULTS

In our work we follow the procedure adopted in medical microbiology: if the infective agent causing a definite pathological condition is to be determined, the entire microbial community causing the pathological condition is studied and an attempt is made to reproduce the same pathological condition by inoculating each species of the suspected infective agents from the original host into another host, i.e. a pure culture into another host. We acted similarly: by culturing the steel samples with individual species of bacteria, which contribute the group of products affecting the corrosion of steel, we attempted to evaluate the effect of each species of bacteria on the corrosion of the test samples.

Not all of the bacteria that were individually investigated stimulated the biocorrosion of steel, despite the fact that they, in a group, undoubtedly created corrosional processes. The causes of such a phenomenon lie in the differences in the intensity of reproduction and activity of bacteria. Only the bacteria that are characterized by intense development, and by production of large quantities of hydrogen sulfide or ammonia, further the biocorrosion of steel in experiments.

When comparing the data of tests with those found in literature, one may conclude that the greater part of the investigated species of bacteria stimulate the corrosion of stainless and carbon steel samples in sea water. The effect of bacteria lies in the fact that they act as depolarizers, which in aerobic conditions oxidize the molecular hydrogen that is liberated on the cathode (V. desulfuricans), or fix it in aerobic conditions by deaminating peptone (saprophytic bacteria). The carbonic acid, accumulating as a result of gas exchange of bacteria and being the final product of oxidation of organic matter, disrupts the passive surface film of metal. The activation of the protective surface film displaces sharply the electrode potential toward the negative side, intensifying the self-solution of steel. Hydrogen sulfide and ammonia, which are produced by bacteria and act as corrosional agents, form well pronounced corrosion products when coming in contact with iron — namely: ferrous sulfide and hydrate of ferric oxide.

In addition, the corrosion process of stainless steel must be specifically protected. Owing to the compositional parts of stainless steel, a thicker protective film is formed on it, which protects the steel from corrosion. It is many times more difficult to destroy this film than that of the carbon steel and cause the corrosion of stainless steel. Considerable corrosional damages of stainless steel are observed only when the action of V. desulfuricans cultures on the metal is longer. The contribution of the bacteria to the formation of hydrogen sulfide depolarizes the cathodes of microgalvanic elements by oxidizing the molecular hydrogen, thus sustaining the effect of galvanic couples without creating considerable corrosional damages of the metal. Then, due to the utilization of organic matter in the medium, unfavorable conditions for bacteria are created, and their reproduction ceases. Such conditions are created for stainless steel after 125 to 150 days from the beginning of the tests. During this time, the sulfate-reducing bacteria intensify the absorption of molecular hydrogen, and the corrosional losses to the metal become clearly pronounced. Therefore, it is obvious that the main corrosional activity of sulfate-reducing bacteria begins when the organic matter of the nutrient medium is used up, and when the depolarizing role of the bacteria manifests the most intensity.

Despite the fact that the weight loss to the samples of stainless steel in the tests equalled rerely 0.9 g/m^2 and made up merely 0.01°/o of the metal mass, the local biocorrosion of individual samples reached 126 g/m^2, which makes up about 1.5°/o of the weight of the metal. Especial attention need be paid to this phenomenon. Indeed, when individual segments on the surface of the steel plates are damaged, especially effective centers of corrosion may arise, as a result of which deep cavities creating considerable damage to the stainless steel may appear.

CONCLUSIONS /244

1. The depolarizing role of sulfate-reducing and saprophytic bacteria on electrochemical corrosion of stainless and carbon steel samples, exposed to sea water, has been demonstrated.

2. The V. desulfuricans culture, which was utilized in the tests, appears to be very active. Its reproduction on the surface of metal samples is intense, reducing the sulfates and forming in 30 days in the Tausson medium as much as 368.5 mg/ℓ of H_2S, and in sea water as much as 43.8 mg/ℓ of H_2S.

3. The reproduction of V. desulfuricans on the surface of stainless steel IX18H9T and the formation of hydrogen sulfide in the medium occur only during 150 days. Afterwards, the number of bacteria decreases and the formation of hydrogen sulfide ceases.

4. The greater portion of the bacteria investigated stimulated the biocorrosion of carbon steel.

5. Only the bacteria which are reproduced intensely and have a clearly pronounced capability of forming hydrogen sulfide or ammonia appear to stimulate the biocorrosion of carbon steel.

6. The activity of bacteria creates considerable corrosional losses of carbon steel, while the electrochemical corrosion in the sterile media occurs at a less intense rate.

7. The biocorrosion of stainless steel in V. desulfuricans cultures is noticeably manifest only when the cultivation is lengthy (more than 150 days), when the organic substances of the medium have been utilized and the absorption of molecular hydrogen by bacteria, which sustains the depolarization of cathodes of microgalvanic elements, is intensified.

8. Iron sulfide furthers the biocorrosion of carbon steel in the following bacterial cultures: V. desulfuricans, Bac. tenuissimus, Bac. aridus, Bac. subtilis, Bac. nitidus, Bact. agile, and M. albicans.

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THE INFLUENCE OF ALGAE ON THE CORROSION OF CARBON STEEL IN SEA WATER AND THE EFFECT OF ULTRASONIC VIBRATIONS ON THE INTENSITY OF ALGAL PHOTOSYNTHESIS

Abstract

The corrosion of carbon steel in sea water increases by about 20% under the action of photosynthesis of the green alga Enteromorpha. Photosynthesis leads to a greater expenditure of electrical energy for cathodic protection. A rise of oxygen concentration from 7 mg/ℓ to 10 mg/ℓ requires a 50% increase of current density to reach a protective potential.

Ultrasonic vibrations exert a marked depressing influence on the photosynthetic activity of Enteromorpha. Even at low intensities of sonic pressure, such as 0.01 — 0.02 W_t/m^2, the photosynthesis was noticeably reduced.

A number of investigations, conducted during the past years, demonstrate that fouling organisms on vessels and hydrotechnical structures exercise great influence on corrosion processes of metals. Thus, in a number of cases, influenced by animals, the rate of corrosion decreases considerably (Tarasov, Ulanovskiy, 1960; Ulanovskiy, Turpayeva, Korovin, Simkina, 1961). In other cases, however, the animal fouling appears to be a cause of intense corrosion (Ulanovskiy, Tarasov, Korovin, 1959; Ulanovskiy, Turpayeva, Korovin, Simkina, 1961). A substantial influence on corrosion is also exercised by bacteria which appreciably intensify the destruction of metals (Rubenchik, 1950; Nikitina, Ulanovskiy, 1957; Rosenberg, 1961, etc.). However, it was not until recently that enough attention was paid to the influence of algae on the corrosion of metals. There are only a few papers that mention the acceleration of steel corrosion resulting from photosynthesis of algae (Barriety, Debyser, Hache, 1957; Hache, Barriety, Debyser, 1959; Hache, 1960a, b).

THE METHOD

The investigations were conducted in laboratory conditions and in the Black Sea. In laboratories, the effect of photosynthesis of algae on corrosion was investigated under artificial lighting by ДС lamps (daylight lamps). The illumination equalled 1350 ℓk (lux), and the temperature was 20-21° C. The Black Sea alga Enteromorpha compressa (L.) Grev. was used in the experiments. The algae were carefully separated from the concrete seawalls on the coast in the area of Odesskiy zaliv (Odesskaya bukhta). Algae of various sizes that had not been washed off were used for the tests. The tests were conducted in open and hermetically closed glass containers 0.6 ℓ in size and 140 mm high, which contained filtered sea water. Algae whose absolute dry weight was 0.23 — 0.26 g were put into hermetically closed containers, while algae whose weight equalled 0.4 — 0.5 g were put into open containers. The intensity of photosynthesis was calculated on the basis of liberated oxygen, the concentration of which was determined by the Winkler method. Ground samples of Ст-3 steel, 30 x 15 x 2 mm in size, were used in the tests. Prior to the tests, the surface was degreased with acetone. After the tests, the corrosion products were removed by cathodic processing. The steel samples and algae were simultaneously placed into containers. The control tests were conducted in an analogous way, but without algae.

In the tests designed for the study of ultrasonic vibrations on the intensity of photosynthesis of Enteromorpha, an ultrasonic generator with magnetostrictive transformers was used, the frequency of vibrations being 21 — 25 k hertz. The power of the generator was 10 watts. The transformers with a radiation surface of 1.5 cm^2 were soldered to the samples with the same transverse sections and a length equalling that of the wave. The algae were subjected to the action of ultrasonic vibrations in containers 0.6 ℓ in size with the aid of the samples submerged in water to a depth of 120 mm. Control tests without ultrasonic vibrations were conducted simultaneously. The measurement of intensity of sonic pressure in the liquid was conducted by the acoustic sounding device АЗ-3 with the aid of a spherical pressure receiver having the sensitivity of E = 1.6 mkv/bar (microwatt). The intensity of sound pressure is shown in watts per square meter (according to ГОСТ (All-Union State Standard) [illegible]49-5[illegible]). In order to eliminate the standing waves, formed in containers having finite sizes as a result of the reflection of sound waves, the bottom of the container was insulated by porous rubber. /247

THE RESULTS OF TESTS

The corrosion rate increases under the influence of photosynthesis of Enteromorpha (Table 1). This is explained by the fact that in the process of photosynthetic activity a large quantity of oxygen is released into the surrounding medium; and one of the main factors determining the rate of corrosion of carbon steel in sea water is the concentration of oxygen -- corrosion increases proportionally with an increase of the latter. Despite a relatively weak illumination in the test (1350 lux), a considerable quantity of oxygen was freed during the process of photosynthesis (Table 1). After 24 hours of testing, the quantity of oxygen increased 2.5 times, but after 48 hours the quantity increased three times in comparison with the beginning of the test (7.43 mg/ℓ). In connection with the use of oxygen for corrosion, its concentration in the control tests decreased all the time. The corrosion rate with photosynthesis considerably increased: in 24 hours it exceeded twice the rate in the control tests, but in 48 hours the rate was increased three times.

Table 1

The Effect of Photosynthesis on the Rate of Corrosion of Cт-3 Steel in Hermetically Closed Containers (the tests were conducted in October)

Time of test, hours	Absolute dry weight of algae, g	In the presence of algae		Control	
		corrosion rate, g/m^2/hour	O_2 concentration by the end of test, mg/ℓ	corrosion rate, g/m^2/hour	O_2 concentration by the end of test, mg/ℓ
24	0.26	0.294	19.64	0.141	5.19
48	0.23	0.225	23.56	0.071	3.60

In open containers, i.e. in conditions that approximate natural circumstances, the corrosion rate in the presence of photosynthesis was also increasing. In 24 hours of tests in the presence of photosynthesis, the corrosion rate exceeded 30% of that of the control sample, but in five days the rate was twice as much as in the control sample (Fig. 1). Despite the fact that the containers were open, the oxygen concentration continually increased and in five days reached 19.3 mg/ℓ, exceeding twice the original concentration.

The experiments conducted in the sea are confirmed by data obtained under laboratory conditions; under the influence of algae, the corrosion rate of carbon steel considerably increased. When the experiments were conducted in natural conditions, the steel samples were submerged in water in places where the algae fouling was most intense. In these conditions it was difficult to study the influence of a given alga, because various algae constituted the fouling. After the tests the samples that were completely fouled, mainly with algae, were collected. In addition to <u>Enteromorpha</u>, which constituted the main portion of fouling, other species of green algae also were found, including red algae. The control samples were collected from locations where the algal fouling was insignificant. After six months of testing (from April through October), it was found that the corrosion rate increased on the average by $20^{\circ}/_{0}$ when the algal fouling was intense (Table 2). Approximately the same results were observed in algal foulings on samples of low-alloy steel.

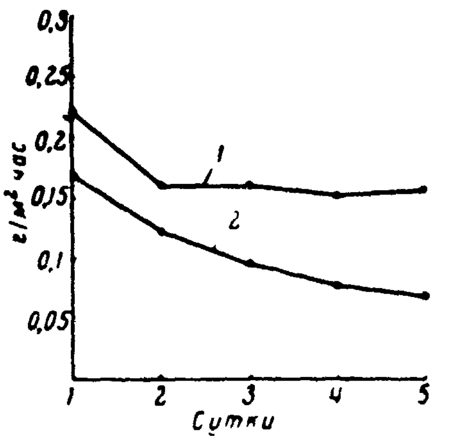

Fig. 1. The effect of photosynthesis of <u>Enteromorpha</u> on the corrosion rate of Cт-3 steel in g/m^3/hour in open containers.

Vertical line: g/m^2/hour
Horizontal line: days.

The increase of oxygen concentration, owing to photosynthesis, also shows a great effect on the cathodic protection. The value of the potential of metal, at which corrosion ceases, is known as the protective potential. The calculated value of the protective potential for steel in laboratory conditions equals −0.61[illegible] watts (Zhuk, 1957). The density of the current, that is

Table 2

The Rate of Cт-3 Steel Corrosion (in g/m^2/hour) at Algal Fouling on Test Panels in the Sea

Number of Sample	Samples with Algae	Control Samples
1	0.066	0.062
2	0.075	0.058
3	0.071	0.055
4	0.069	0.061
5	0.073	0.059
Mean rate of corrosion	0.071	0.059

necessary for the cessation of corrosion, is determined by the intersection point of the curve of cathodic polarization and the straight line corresponding to the protective potential. It is seen from Fig. 2 that, with the absence of photosynthesis, the density of current in cathodic protection that is needed for reaching the protective potential must equal about 0.016 ma/cm^2. With an increase in the concentration of oxygen to 10 mg/ℓ in the presence of photosynthesis, the needed density of current increases to 0.024 ma/cm^2, but if the concentration of oxygen is 11.2 mg/ℓ, the corresponding density of current is 0.029 ma/cm^2.

It is seen from the listed data that the enteromorphic fouling causes great damage at cathodic protection. Even a small increase in the concentration of oxygen, if photosynthesis reaches 11 mg/ℓ, almost doubles the required electrical energy.

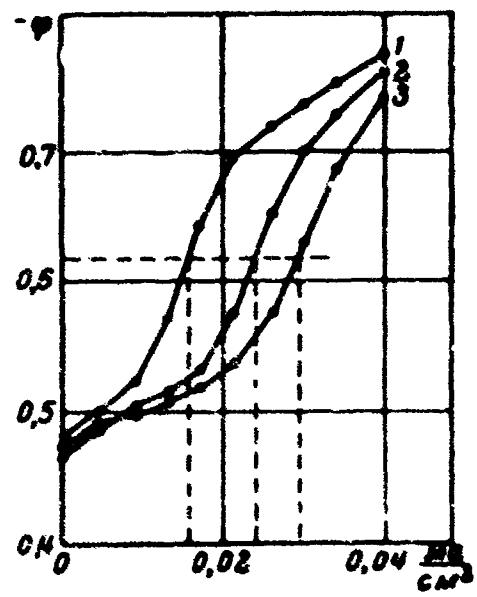

Fig. 2. The effect of photosynthesis of Enteromorpha on the protective density of current.

1 — polarized cathodic curve without photosynthesis, the oxygen concentration being 7.1 mg/ℓ; 2 — polarized cathodic curve with photosynthesis, the oxygen concentration being 10 mg/ℓ; 3 — polarized cathodic curve at photosynthesis, the oxygen concentration being 11.2 mg/ℓ.

Ultrasonic equipment has been used lately for fighting the fouling on the underwater parts of vessels. In connection with a considerable influence of photosynthesis of algae on the process of corrosion of carbon steel, the investigation of the effect of ultrasonic vibrations on the intensity of photosynthesis has gained momentum.

Our data demonstrated (Table 3) that the ultrasonic vibrations obstruct the photosynthesis of algae even if the intensity of sound pressure is slow. Thus, in tests conducted in October, irradiation with ultrasonic sound created more than a twofold decrease of photosynthesis. With a decrease of intensity of photosynthesis, the influence of ultrasonic vibrations was intensified. In tests, which were conducted in December, the intensity of sound pressure, being even as low as 0.01 $watts/m^2$, diminished the intensity of photosynthesis six times. In one of the tests, even the original concentration of oxygen was diminished.

The effect of ultrasonic vibrations on the activity of algae is manifest not only during the period of their irradiation, but also after the irradiation (Table 4). Just after the irradiation by ultrasonic sound the photosynthesis differs little from that of the control sample. The attenuation of photosynthesis in the given test constituted

Table 3

The Effect of Ultrasonic Vibrations on the Intensity of Photosynthesis of Enteromorpha

Test	Time of testing	Quantity of O_2, mg, liberated in a day per 1 g of dry mass of algae		Intensity of ultrasonic pressure, watt/m^2
		at ultrasonic vibrations	control sample	
1	October	49.03	121.15	0.02
2	"	28.04	76.49	0.02
3	"	119.08	163.22	0.02
4	December	9.94	33.5	0.01
5	"	3.83	20.17	0.01
6	"	—2.74	10.55	0.01

about 15%. However, in just 24 hours of irradiation by ultrasonic sound the algae liberated 40% less oxygen than the control samples, but in 48 hours the difference in the intensity of photosynthesis between the irradiated and control samples reached 60%. Thus, the intensity of photosynthesis of algae continually decreased after irradiation.

A decrease in the value of pH was observed during the given tests, the rate being 0.2—0.3. Such a variation of pH does not exercise a substantial influence on steel corrosion. /250

Table 4

The Intensity of Photosynthesis of *Enteromorpha* after the Ultrasonic Vibrations are Switched Off

Time after irradiation, hours	The quantity of O_2, mg, liberated in a day per 1 g of dry mass of algae	
	irradiated algae	control samples
0	13.73	15.89
24	22.56	33.50
48	8.28	20.17

CONCLUSIONS

1. The corrosion of carbon steel in sea water is considerably intensified under the influence of photosynthesis of *Enteromorpha* (green alga). The corrosion rate increases by approximately 20°/o.

2. As a result of photosynthesis of algae, the use of electric energy in cathodic protection of carbon steel in sea water is greatly increased. Thus, if the oxygen concentration is increased only to 10 mg/ℓ, the current density that is needed for obtaining the protective potential increases by 50°/o.

3. The photosynthetic activity of *Enteromorpha* is considerably diminished by the action of ultrasonic vibrations. Its photosynthesis was noticeably diminished even at low intensities of sound pressure, ranging from 0.01 to 0.02 watt/m^2.

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INVESTIGATION OF THE ACTION OF NEW ANTIFOULING PAINTS ON THE LARVAE OF THE POLYCHAETA WORM MERCIERELLA ENIGMATICA FAUVEL AND ON YOUNG BIVALVE MOLLUSKS MYTILUS GALLOPROVINCIALIS L.

Abstract

The toxic action of some experimental antifouling paints was studied under laboratory conditions. A combination of P-oxide and copper protoxide in these paints, which provided an effective protection against fouling in the sea, was found less toxic in laboratory tests than a combination of copper protoxide and oxide of mercury.

Special antifouling paints containing toxic substances, mainly the compounds of mercury, copper and arsenic, but in individual cases also organic toxins, are used at the present time for the protection of underwater parts of the hulls of vessels from marine fouling. Up to the present time, our paint industry has developed the NIVK paints, the effect of which is of short duration, about six to nine months. Since 1961, our paint industry has begun to develop new and more effective antifouling paints, formulated by the Leningrad Branch of the State Scientific-Investigational and Planning Institute of the Paint Industry (GIPI-4). These brands of paints include KP-24, KP-29 (BTУ ЯН-27—60), XB-53 (BTУ ЯН-187—60), and XC-77 (BTУ ЯН-186—60)*. The effect of these paints lasts 2 to 2.5 times longer than the former.

As is known, the duration of the effect of paints depends on the quantity of toxic substances and on the rate with which they leach in water. The speed of leaching, in a long time period, depends upon the composition of the paints (the nature of chemically combined toxic substances, the volume concentration of the substances, etc.), as well as upon the physical-chemical characteristics of sea water (upon the

*Translator's note. For better identification of the types of paints, the Russian letter symbols were not transliterated into English. KP denotes kraska-paint, etc.

concentration of chlorine ions, temperature, mixing of the solution that comes in contact with the painted surface, etc.). The intensity of leaching of poison from the surface of paint is not similar in time. The initial speed of leaching is distinguished from the stable speed. The leaching with initial speed occurs, as a rule, during a brief time interval (approximately a month after painting). The stable speed of leaching is preserved during a long time period at approximately the same level, provided the paint is good.

The studies of American investigators have established that the initial speed of leaching of copper is considerably below the stable speed, and that if copper is leached with a speed of at least 10 $\mu g/cm^2$ a day, it deters the marine fouling altogether. In order to deter marine foulers with paints containing copper compounds, other toxic substances should be added to the former — substances characterized by a high speed of leaching during the initial period (mercury, for instance). In addition, the introduction of certain inorganic or organic poisons into the composition of copper paints may secure their /253
effective action when the copper is leached with speeds not reaching 10 $\mu g/cm^2/day$.

This study discusses the results of testing the action of leachates of antifouling paints KP-24, XB-53 (formerly 0-XB-70—7), XC-79, paint 92, and experimental paints No. 13, 15 and 16, which contain only one toxin.

THE METHOD

For the preparation of leachates, the glass objects covered with a layer of antifouling paints were placed into conical containers with sea water. As a rule, eight glass objects with the total painted area equalling 137.5 cm^2 were placed into each container, the water volume of which was 250 cm^3. After 10 days, the leachates were poured into flasks with ground corks, where they were kept in darkness until the beginning of the tests. Altogether, the action of seven leachates of the same paint, prepared at various times, was tested. Leachate I was prepared just after the painting of glass objects, leachate II was prepared after 20 days, leachate III after 60 days, leachate IV after 100 days, leachate V after 140 days, leachate VI after 450 days, and leachate VII after 500 days. In the intervals between the periods of leachate preparations the painted glass objects were leached in running sea water.

Twenty larvae of M. enigmatica were placed into a drop of water in cups with a round bottom 5 cm in diameter and 4 cm in height. Afterwards, 20 cm^3 of leachate was poured into the cups. Because a daily replacement of water is required for the existence of the larvae in laboratory conditions, the maximum duration of tests was 24 hours. The test was considered as completed after 100°/₀ of the larvae had perished.

Ten or twenty young M. galloprovincialis individuals, 4-6 mm long, were placed in test containers; the leachate, forming a layer 6-7 mm thick, was poured into the containers so that the mollusks were covered with the liquid. The mollusks were kept in the leachates for 10 days. If the test animals did not perish during this time, the test was discontinued. The test was considered completed after 100°/₀ of the mollusks had perished. The death of mollusks was determined by the absence of reaction to irritation.

THE RESULTS OF LABORATORY TESTS

The larva of M. enigmatica do not react at once to the toxic substances of the leachate after they have been placed into the liquid. At the beginning, they continue to float and their behavior in no way differs from that in sea water. After a certain time, in several minutes or hours, depending upon the toxic character of the leachate, the larvae sink to the bottom of the cup and their behavior is reminiscent of settlement. They creep along the bottom of the cup, sometimes stopping. at other times floating. Gradually the motion of the larvae slows down, the protoplasm becomes turbid (grainy), the larva lies on the bottom, sometimes even sticking to it, and dies. Transplantation of larvae lying on the bottom to sea water did not save them from perishing. The results of the tests (Table 1) demonstrate that the time period during which the larvae perish in the leachates of KP-24, XC-53, and XC-79 was considerably shorter than in the leachates of the subsequent paints. The high toxic character of leachates of paints KP-24 and 92 is, evidently, determined by the presence of mercury in the paints, which is readily leached.

Young M. galloprovincialis (Table 2) placed into leachates of anti- /254
fouling paints lie, at the beginning, on the bottom of the cup, their tubules being tightly closed; then the tubules are opened and they begin to filter the leachate. If the mollusks sense the toxic substance at once, they close the tubules again and remain in such a position until the end of the test or until they perish.

Table 1

Time During which the Larvae of M. enigmatica Perish in the Leachates of Antifouling Paints

Paint	Toxins Composing the Paint	Number of Leachates			
		I	II	III	IV
		Time during which the larvae perish, hours			
KP-24	Cuprous oxide, mercuric oxide, P-oxide.	1	13	13	24
XC-53	Cuprous oxide, P-oxide, zinc oxide.	5	12	24	6
XC-79	Cuprous oxide, P-oxide	2	12	12	—
92	Cuprous oxide, mercuric oxide (considerable quantity). . . .	0.6	0.6	1	—

If, however, the mollusks do not perceive the toxin, they let out their legs and begin to creep on the bottom of the cup and they may even attach themselves to the glass; their tubules remain partly open all the time. A comparison among the leachates of experimental paints with one toxin demonstrate that the most poisonous to mytilaceans was the leachate of paint 16 (with mercury oxide), in which the young mollusks perished within a few days. The least poisonous to mytilaceans appeared to be the leachate of paint 13 (with cupric [cuprous] oxide)[1]. The mytilaceans lived in the liquid more than 10 days, after which the test was discontinued. It is possible, that this fact is associated with the above-mentioned retarded speed of leaching of copper ions from the paint film just after the paint is applied. The first leachates of the remaining experimental paints also exercised a dissimilar influence on the mytilaceans. Within three days, the leachate of KP-24 killed the test animals, which is evidently caused by the

[1] The tested mollusks evidently sensed the toxicity of the leachate of paint 15 (sic! 16), because during the entire test the tubules of the animals remained tightly closed.

Table 2

Time During Which the Young M. galloprovincialis Perish in the Leachates of Antifouling Paints

Paint	Toxins Composing the Paint	Number of Leachates			
		I	II	III	IV
		Time during which the larvae perish, hours			
13	Cuprous oxide.	10	—	—	—
15	P-oxide.	10	—	—	—
16	Mercuric oxide	1	—	—	—
92	Mercuric oxide, cuprous oxide.	10	4	3	—
XC-79	Cuprous oxide, P-oxide	4	3	4	—
XB-53	Cuprous oxide, zinc oxide, P-oxide.	3	3	4	3
KP-24	Cuprous oxide, mercuric oxide, P-oxide.	3	4	2	2

presence of mercuric oxide in the paint. The slow effect of the leachate of paint 92, consisting of a considerable amount of mercuric oxide, is due to the fact that in this leachate the tubules of the mollusks remained closed almost all the time. Evidently, the mytilaceans had sensed immediately the toxic character of the leachate.

The variation in the effect of paints KP-24 and XB-53 with time is disclosed by data on the survival of M. galloprovincialis in seven leachates of the paints (Table 3). Leachates I — V, prepared during the first 150 days after painting, exercised a rather great effect on the mytilaceans, the intensity of which, nevertheless, noticeably changed. The action of leachates III and IV of paint KP-24, which killed the animals within two days, was the most effective. Five months after painting the effect of both of the paints (leachates VI and VII) becomes stabilized for a rather lengthy time period. /255

Such a variation in the toxicity of leachates is determined by a non-uniform leaching of various toxic substances from the film of the given paint. A high degree of toxicity of leachates III and IV of paints KP-25 is, evidently, associated with the action of mercury ions and, possibly, also with a combined action of mercury and copper ions. It is known from the literature (Marine Fouling and Its Prevention, 1957) that a joint effect of small concentrations of copper and mercury is usually greater than could be expected on the basis of the sum. Stubbings (1953) explains this phenomenon as follows. Copper is a poison of general action, binding, in the first place, the respiratory pigments. It can be readily ejected from the organism, and therefore

Table 3

The Effect of Various Leachates of Paints KP-24 and XB-53 on Young Mytilaceans
(survival in °/o; numerator is in leachates of paint KP-24, denominator is in leachates of paint XB-53)

Number of leachates	Time of leaching of paint on the plate	Duration of test, days							
		1	2	3	4	5	6	7	8
		Death of young, °/o							
I	0	80/50	60/30	0/0	—	—	—	—	—
II	20	80/90	20/40	20/0	0	—	—	—	—
III	60	60/90	0/40	0/20	0/10	0/0		—	—
IV	100	60/70	0/50	0/0	—	—	—	—	—
V	140	65/100	55/45	25/30	5/10	0/0	—	—	—
VI	450	100/35	50/25	30/25	5/15	0/0	—	—	—
VII	500	100/95	50	40/35	20/5	25/5	10/5	5/5	0/0

low concentrations of copper do not exercise a great influence on marine invertebrates. In contrast to copper, mercury affects mainly the secretory system, paralyzing its functions. In the solutions of mercuric salts, the animals are poisoned mainly by their own decomposition products. In weak solutions of mercury and copper compounds, where the concentration of both of the toxins is below the lethal point, mercury obstructs the secretory system, aggravating the liberation of copper from the organism, which rapidly accumulates and leads to a complete poisoning of the animal.

Thus, on the basis of our tests with paints, the most effective paints in the initial period appeared to be the paints containing mercuric oxide - which is a very strong and readily soluble toxin. The P-oxide, which is also characterized by effective toxic properties (Iskra et al, in this compilation of papers), exercised a weaker effect in the leachate of XC-79 and XB-53 paints, which may result from its limited solubility. The least effective toxin appears to be cuprous oxide. However, the stability of the effectiveness of paints KP-24 and XB-53 during the period from 150 to 450 days after their application is evidently, determined mainly by cuprous oxide, which is known for its ability of uniform leaching from paints during a lengthy time period.

When comparing the effect of leachates of the tested paints on larvae of M. enigmatica and young M. galloprovincialis, a considerable difference in the reaction of the animals to the toxic leachates need be pointed out. The larvae of M. enigmatica have to be considered as being more sensitive test objects than young M. galloprovincialis. Thus, the time of their death in various leachates of paint KP-24 varied 10-20 times (see Table 1). We did not detect analogous sensitivity to various leachates in young mytilaceans. Usually, the time of their death varied only 2 to 2.5 times (see Table 2).

TESTING PANELS WITH EXPERIMENTAL PAINTS IN THE SEA

Simultaneously with testing the paints under laboratory conditions, we conducted tests on the process of marine fouling on painted panels exposed to sea water. For this purpose, the painted glass panels, 9 x 12 cm in size, were exposed to sea water in Gelendzhikskaya bukhta in May 1958.

The examination of the panels by the end of the test, which is pointed out in Table 4, demonstrated that paints KP-24, XC-79, and XB-53 have good protective characteristics preserving their effectiveness for 1 1/2 to 2 years. Insignificant fouling by barnacles was noted only on panels painted with No. 92 paint.

Table 4

Results of Examination of Glass Panels Covered with Experimental Paints (Gelendzhikskaya bukhta)

Type of paint	Duration of test, months	Fouling	Preservation of paint layer	Notes
KP-24	24	No	Individual cracks	No fouling in the cracks of paint on glass or in empty spots
XC-79	24	No	Good	—
XB-53	18	No	Good	—
92	16	Insignificant	Individual cracks	—

The determination of antifouling characteristics of experimental paints on a larger scale was conducted in Sevastopol'skaya bukhta (bukhta Severnaya). The paints were applied to metal panels (steel and duraluminum) 250 x 350 mm in size in various patterns, taking into consideration the protection from corrosion and fouling.

The paint that remained unfouled always consisted of two layers of paints KP-24, XB-53, and XC-79.

The panels were submerged into the sea in the spring (May-June) and autumn (October-November), which, in addition to other factors, enabled us to elucidate the effectiveness of paints during the period of intense fouling and the period preceding it, i.e. several months after the panels with antifouling paint had been exposed to sea water, which was almost devoid of the larvae of foulers. /257

The condition of the paint was examined each half a year (in autumn and spring). The total length of time during which the panels were kept in the sea was 2 to 2.5 years (including two summer seasons).

An examination of the exposed panels, which was done by the end of the test (Table 5), demonstrated that the greater part of the painted samples did not have any fouling during the two summer seasons. The greater part of the fouled panels contained insignificant numbers of barnacles and only a few of the panels were covered by foulers, the fouled surface not exceeding 50°/₀. The fouling was found on panels

Table 5

Results of Examining Test Panels in Sevastopol'skaya bukhta (bukhta Severnaya) during Two Summer Seasons

Type of paint	Number of samples		Percentage of fouled samples relative to the number of panels
	submerged for testing	fouled	
KP-24	18	3	16.7
XB-53	29	3	10.4
XC-79	84	11	13.1

which had not been painted in accordance with the established rules: the paint layer was either too thin (as a result of excessive dilution), or the samples had been exposed to the air for a long time period (more than a month) prior to their submergence, etc. In addition, almost 70°/₀ of the fouled panels had been submerged into sea water at a time when the settlement of larvae reached its peak (June-July). The latter condition emphasizes once more a certain delay in the efficiency of toxins in antifouling paints during the initial period of exposure of panels to the sea water.

CONCLUSION

The conducted experiments demonstrated that the most effective toxin of the antifouling paints is mercuric oxide. The P-oxide demonstrated a somewhat weaker effect on the larva of M. enigmatica and young M. galloprovincialis than the mercuric oxide; cuprous oxide appeared to be still weaker. A combination of P-oxide and cuprous oxide secured an effective protection from fouling; however, according to laboratory tests, the combination appeared to be less effective than a combination of cuprous oxide and mercuric oxide. Paints KP-24, XB-53, and XC-79 have to be considered sufficiently effective for their utilization as antifouling paints. A disregard of techniques in the application of paints is absolutely inadmissible; discrepancies may cause a premature fouling on the protected surface.

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THE EFFECT OF SOME TOXIC SUBSTANCES ON THE MAIN FOULING ANIMALS OF TAGANROGSKIY ZALIV

Abstract

Among the 19 toxic substances tested, sodium pentachlorophenolate was found to exert the strongest toxic effect on P. megas and on B. improvisus. The return of the hydroids and barnacles, subjected to the action of sodium pentachlorophenolate, to normal life activity is so slow that this poison can be effectively used.

In view of the large extent and multiple ramification of the water supply system of various plants, chemical methods are used, by adding small quantities of soluble substances to the water, in the protection of technical water conduits from marine fouling. Most frequently liquid chlorine, the residue concentration of which, consisting of 1 mg/ℓ, slowly kills fouling animals, is added to the water (Marine Fouling and Its Prevention, 1957); a concentration of 0.25 mg/ℓ of the chlorine stops growth (Turner et al, 1948). The application of liquid chlorine is profitable only when the water pollution is limited. With a considerable pollution of water with organic substances, the chlorine-absorption of water increases greatly; because of this, the amount of chlorine needed for the prevention of fouling increases to such a degree (in individual cases it may reach 12 to 15 mg/ℓ) that the use of chlorine becomes unprofitable. In this case, one may apply the method of vitriolation worked out by G. Ye. Krushel' in the USSR (1950). This method consists of adding a concentration of 6-7 mg/ℓ of copper sulfate to water. However, the application of the method of vitriolation may create an intensification of corrosion on the inner surface of water pipes because of the formation of an electrical couple.

In addition to the use of inorganic substances in the prevention of marine fouling on water pipes, prospects of using various organic toxins for this purpose were also investigated. Some of them, notably pentachlorophenol, were successfully used for the prevention of fouling in water pipes designed for tests (Marine Fouling and Its Prevention, 1957). Turner et al (1948) recommend the use of sodium pentachlorophenolate for this purpose, which stops the growth of fouling animals at a concentration of 0.25 mg/ℓ in laboratory conditions.

This study discusses the results of tests concerning the effect of various organic and inorganic toxins on the main foulers in Taganrogskiy zaliv of the Sea of Azov. Because of considerable water pollution in the area, the application of liquid chlorine for the prevention of fouling in water pipes is not rational.

THE MATERIAL AND METHOD

The effect of toxic substances was investigated in two basic components of fouling fauna: the hydroid polyp Perigonimus megas Kinne and the cirripedian crustacean Balanus improvisus Darwin.

The hydroid colonies that were needed for the tests were collected /260 from the grids of pump stations of the plant and dispatched immediately to the testing laboratory. New segments of stolons from 10 to 20 active hydranths were cut off from the colonies with a scalpel and put at once, singly, into Petri dishes with toxic substances, where they were kept for one to five days depending on the condition of the hydranths.

After the tested hydranths had completely lost their sensitivity, the toxic solution was replaced by sea water for three to five days in order to establish whether the given substance decreases in the hydroids or the activity of the colony can be restored.

The barnacles for the tests were collected in the sea, near the coast, or from stones. Because our tests were conducted only in the autumn, sexually mature animals were used. The stones fouled by barnacles were smashed in the laboratory and their pieces with determined numbers of barnacles were placed into glass containers containing 0.5 ℓ of toxic solution. The barnacles were kept in these conditions for several hours or days, until they ceased to react to stimulants; afterwards, as in the case of hydroids, they were put into sea water for several days.

Substances that can be readily dissolved in water and those that can be dissolved with difficulty were investigated. The substances whose solution was easy were tested in concentrations of 10 and 1 mg/ℓ. If the substance did not manifest a toxic effect in a concentration of 10 mg/ℓ, a concentration of 100 mg/ℓ was used. Because the tests required a very large quantity of water, higher concentrations were not considered worthwhile for the testing.

In order to test the substances whose solution was difficult, leachates were made. A definite quantity of substances — 100 or 10 mg — was put into 1ℓ of water for 24 hours.

THE RESULTS OF TESTS

Of all the tested organic toxins (Table 1 and 2), pentachlorophenolate appeared to be most effective for hydroids. Even the lowest concentrations (1 mg/ℓ) exercised a considerable toxic effect on hydroids (Table 1). The total number of hydranths in the test decreased gradually, reaching 7°/o of the initial number on the sixth day. The effect of sodium dinitroortho cresol of the same concentration was considerably smaller: about 40°/o of hydroids were alive on the sixth day.

Because all of the hydranths did not perish in the mentioned concentration of toxins, the animals were not transferred into sea water after the test in the solution.

Of the inorganic compounds, copper sulfate in a concentration of 1 mg/ℓ appeared to be most effective (Table 1). Only 2°/o of hydranths remained alive after two days in the solution. As the colony was transferred to sea water, it began to revive slowly: only 18°/o of the hydranths had revived on the fourth day in sea water.

Sodium trichlorophenolate and calcium hypochlorite in a concentration of 1 mg/ℓ were almost without effect on the hydroids.

The concentration of 10 mg/ℓ appeared to be very poisonous in three readily soluble organic compounds — sodium pentachlorophenolate, sodium trichlorophenolate, and sodium dinitroortho cresol. All of the hydranths perished within three days when kept in solutions of these chemicals. When transferred to sea water, the colonies recuperated. However, the rate of recuperation of the animals exposed to these chemicals was dissimilar. The most rapid rate of recuperation was observed in animals exposed to the action of sodium dinitroortho cresol.

In just one day 30°/o of the hydranths recovered when transferred to sea water, but in three days the colony recovered almost completely. The recuperation of the animals kept in the solution of sodium trichlorophenolate was somewhat slower. The slowest recuperation rate was observed in animals exposed to sodium pentachlorophenolate: only 5 to 6°/o of the initial number of hydranths recuperated on the fourth and fifth days. Even a brief (one day) effect of sodium pentachlorophenolate having the concentration of 10 mg/ℓ caused the death of all the hydranths of a colony. The rate of recuperation of colonies varied in connection with the length of the period of exposure to a given solution. It is seen from Table 1 that 75°/o of hydranths recuperated in a day's time after having been exposed to a sodium pentachlorophenolate solution having the concentration of 10 mg/ℓ for a day. The recuperation, after a two-day exposure to the same solution, began on the second day in sea water and occurred at a considerably slower rate: 65°/o of hydranths recuperated in five days. However, after a three-day exposure to the solution, no recuperation of hydranths was observed in five days.

The colonies of hydranths kept in 10 mg/ℓ concentrations of salicylanilide sodium salt, paranitrophenol, and chlorophos (?. sic!) did not perish in three days. Only a partial decrease in the number of hydranths was observed. Even a concentration of 100 mg/ℓ of chlorophos was not sufficiently toxic. But the same concentration of salicylanilide sodium salt was fatal to all of the hydranths; so that their recovery was very slow (?. sic!). Forty per cent formalin was used in concentrations 25, 5, and 2.5 mg/ℓ; only the concentration of 25 mg/ℓ appeared to be effective. The hydroids kept in such a concentration for a day perished completely and could not recuperate. In formalin concentrations of 5 and 2.5 mg/ℓ the activity of the colonies remained normal.

Of inorganic compounds, the most effective concentration for copper sulfate was 10 mg/ℓ. The exposure of hydroids to the solution for a day brought death to the entire colony. The activity of hydroids that were exposed to a 10 mg/ℓ concentration of calcium hypochlorite for three days was rapidly restored in sea water.

The 10 mg/ℓ concentration of the leachate of insoluble sodium salt of P-oxide and diphenyl thiourea appeared to be rather effective (Table 2). They stopped the activity of colonies in a day. If the animals were exposed to the sodium salt of P-oxide for a day, their recovery in sea water was negligible, but if they were exposed to the solution of diphenyl thiourea, the recovery was rather slow; only 45°/o of the hydranths recovered in five days (Table 2).

Table 1

The Effect of Toxic Solutions on Hydroids

Substance	Solution, mg/l	Number of tests	Length of test, days	Total number of live hydranths in test		Variation in the number of hydranths in sea water by days					Number of hydranths in control sample		Notes
				beg.	end	1	2	3	4	5	beg.	end	
Pentachlorophenolate	10	4	2	25	0	0	2	2	12	11	49	45	New stolons appeared when kept in water 5-10 mm
	10	5	3	34	0	0	0	0	2	2			
	10	23	1	165	0	9	122	116	113	—	35	32	Were not kept in water
	1	17	5	153	11	—	—	—	—	—	25	23	
Sodium trichlorophenolate	10	5	3	60	0	0	11	32	52	—	14	23	
	1	10	3	158	180	—	—	—	—	—	20	26	
Sodium dinitro-orthocresol	10	5	3	90	0	29	42	79	—	—	19	16	
	1	10	5	145	54	—	—	—	—	—			
Salicylanilide sodium salt	10	5	3	52	61	—	—	—	—	—	14	22	
	100	5	2	87	0	0	0	0	2	4	24	24	
Paranitrophenol	10	5	3	76	67	—	—	—	—	—	14	17	
Chlorophos *	100	10	2	200	61	—	—	—	—	—	22	17	
	10	5	3	100	32	—	—	—	—	—	28	22	

*O,O-dimethyl-2,2,2-trichloro-1-hydroxyethyl-phosphonate.

Table 1 (cont)

The Effect of Toxic Solutions on Hydroids

Substance	Solution, mg/ℓ	Number of tests	Length of test, days	Total number of live hydranths in test		Variation in the number of hydranths in sea water by days					Number of hydranths in control sample		Notes
				beg.	end	1	2	3	4	5	beg.	end	
40°/o formalin	25	24	1	293	0	0	0	0	0	0	30	34	
	5	5	2	104	180	—	—	—	—	—	18	36	64 young hydranths settled from planules in the test; 10 were in control sample. Sensitivity was good.
	2.5	5	2	98	173	—	—	—	—	—	23	29	
Copper sulfate	10	19	1	248	0	0	0	0	0	0	42	37	
	1	20	2	251	5	0	7	30	45	—	18	16	
Calcium hypochlorite	10	10	3	165	0	150	—	—	—	—	21	31	46 young hydranths settled and transformed in the test; 42 in the control sample
	3	5	3	90	97	—	—	—	—	—	21	32	
	1	10	4	200	168	—	—	—	—	—	18	35	

Table 2

The Effect of Toxic Solutions on Hydroids

Substance	Solution, mg/l	Number of tests	Length of test, days	Total number of live hydranths in test		Variation in the number of hydranths in sea water by days					Number of hydranths in control sample		Notes
				beg.	end	1	2	3	4	5	beg.	end	
A mixture of equal portions of zinc salicylamide and zinc dichlorosalicylamide	20	10	1	147	0	0	0	0	0	0	20	24	35°/o decrease in the test, 33°/o increase in control sample when well fed
	10	20	3	350	223	—	—	—	—	—	33	44	
Dinitroortho cresol	10	10	3	152	5	124	—	—	—	—	20	25	
Sodium salt of P-oxide	10	10	1	180	0	0	12	22	19	1	11	17	
	1	10	3	156	82	—	—	—	—	—	13	18	
Trichlorophenyl ether 2-4 D	10	10	4	156	47	—	—	—	—	—	13	22	
Tetrachlorophenyl ether 2,4,6 T	10	10	3	158	135	—	—	—	—	—	17	12	

Table 2 (cont)

Substance	Solution, mg/ℓ	Number of tests	Length of test, days	Total number of live hydranths in test		Variation in the number of hydranths in sea water by days					Number of hydranths in control sample		Notes
				beg.	end	1	2	3	4	5	beg.	end	
Pentachlorophenyl ether 2-4 D	10	10	3	170	112	—	—	—	—	—	24	12	
α-Naphthol thiourea	10	5	1	87	15	29	55	—	—	—	15	14	
		5	2	79	0	29	43	—	—	—			
Diphenyl thiourea	10	10	1	190	0	14	25	32	57	75	32	24	
Zinc oxide	10	10	3	156	11	—	—	—	—	—	22	18	5 small nudibranchiate mollusks were in the test
DDT*	100	5	4	103	54	—	—	—	—	—	18	22	Weight with talc was 1 g

*Dichlorodiphenyl trichloroethane.

The same concentration of α-naphthol thiourea brought death to all the hydranths in just two days. In a day, 80°/₀ of the hydranths ceased to show activity.

When transferred to sea water from the α-naphthol thiourea solution, the recovery of the colony was rapid. Analogous reaction was observed in the hydranths exposed to a concentration of 10 mg/ℓ of dinitroortho cresol and zinc oxide.

Table 3

The Effect of Toxic Solutions on Barnacles

Substance	Dilution, mg/ℓ	Number of barnacles	Length of test, days	Number of animals losing sensitivity, °/₀	Recuperated in sea water		Number of perished		Number of live barnacles in control sample	
					time, days	number of animals, °/₀	ind.	°/₀	beg.	end
Sodium pentachlorophenolate	10	40	1.0	100	5	0	40	100	10	10
	1	10	1.0	100	2	80	2	20	10	10
	1	12	3.0	100	5	0	12	100	10	10
Sodium trichlorophenolate *	10	18	5.0	22	—	—	4	22		
Chlorophos(?)	100	10	2	100	—	—	10	100	17	15
	10	10	4	100	—	—	10	100	17	15
Sodium dinitroortho cresol	10	12	3	100	—	—	12	100	17	15
	1	8	4	45	—	—	4	50	17	15
40°/₀ formalin	250	20	2.0	100	4	30	14	70	20	20
	250	5	0.2	100	2	100	0	0	20	20
	25	40	2.5	100	5	3	39	97	15	15
	25	20	1.5	100	5	100	0	0	15	15
Copper sulfate	10	15	3	60	4	80	3	20	20	20

*12 ind. faded in the test.

All the other substances of the same concentration which were tested by us appeared to be ineffective. The DDT solution, even in a concentration of 100 mg/ℓ, brought death to only a part of the hydroids. A 50% mixture of salicylamide zinc salts and dichlorosalicylamide was effective only at a concentration of 20 mg/ℓ. The substances that were ineffective for the hydroids were not tested for their effect on barnacles.

Sodium pentachlorophenolate and sodium dinitrocresol were tested in concentrations of 1 mg/ℓ (Table 3). Only sodium pentachlorophenolate appeared to have an effect on barnacles within three days.

Only sodium pentachlorophenolate brought death to 100% of the barnacles within a day when the concentration was 10 mg/ℓ. Sodium dinitroortho cresol of 10 mg/ℓ concentration brought death to 100% of the barnacles in only three days. Still less effective was chlorophos(?): 100% of the barnacles perished in only four days. The other toxins appeared to be ineffective at such a concentration.

A 25 mg/ℓ concentration of formalin killed barnacles and hydroids; however, a longer time period was necessary for the killing of the barnacles. In order to kill all of the barnacles in such a concentration of formalin, at least 2.5 days were needed.

Trichlorophenyl ether and tetrachlorophenyl ether were the most effective of the substances that cannot be dissolved in water (Table 4). The solutions of the toxins in 10 mg/ℓ concentration killed all the tested barnacles in four days. The same concentrations of other insoluble substances appeared to be ineffective.

DISCUSSION OF RESULTS /265

Of the tested soluble substances, sodium pentachlorophenolate and dinitroorthocresol exercised a similar effect on hydroids and barnacles (Table 5). Both of the poisons exercised a depressing influence when applied in the smallest of the tested concentrations — namely, 1 mg/ℓ; in the case of dinitroorthocresol, the effect was very slow (Table 6). Identical data relative to the effect of sodium pentachlorophenolate were demonstrated in a study by Turner et al (1948). The smallest lethal concentration is considered by the authors to be 1 mg/ℓ.

Table 4

The Effect of Toxic Solutions on Barnacles

Substance	Solution, mg/ℓ	Number of barnacles in test	Length of test, days	Number of perished animals		Number of live barnacles in control sample		Notes
				number	°/o	beg.	end	
Mixture of equal portions of zinc salicylamide and zinc dichlorosalicylamide	1000	10	0.5	10	100			7 moltings were observed in test
	10	11	5	2	18			
Dinitroortho cresol	10	10	5	3	30	16	13	5 moltings
Sodium salt of P-oxide	10	11	5	2	18			3 moltings
Trichlorophenyl ether 2,4 D	10	10	4	10	100			
Tetrachlorophenyl ether 2,4,6 T	10	10	4	10	100			
Pentachlorophenyl ether 2,4 D	10	10	5	3	70	17	16	
Zinc oxide	10	10	5	3	70			

The 40°/o formalin having a concentration of 25 mg/ℓ was lethal to hydroids and barnacles. Chlorophos(?) in a concentration of 10 mg/ℓ depressed the activity of hydroids and was lethal to barnacles.

Table 5

Time (in days) of 100°/₀ Destruction of Test Animals in the Solutions of Tested Substances

Substance	Concentration of poison, mg/l			
	hydroids		barnacles	
	10	1	10	1
Sodium pentachlorophenolate. . .	2	5	1	3
Sodium trichlorophenolate. . . .	3	—	—	—
Sodium dinitroortho cresol . . .	3	+	3	+
Chlorophos *	+	—	4	—
Copper sulfate	1	2	—	—
Calcium hypochlorite	3	—		
40°/₀ formalin having a concentration of 25 mg/l		2.5	1	

*+ sign denotes that 50°/₀ or more test animals had perished in a given solution during the length of the test.

Of the insoluble substances, trichlorophenyl ether 2,4 D having a concentration of 10 mg/l was most effective, killing barnacles at a slow rate and depressing the activity of hydroids; besides, zinc oxide of the same concentration depressed the activity of both of the species. The other substances tested by us may be considered as specific agents affecting only one of the tested forms. /266

When studying the effect of the tested substances on mass forms of fouling, one can readily trace the influence of the quantity of chlorine in individual compounds and the class of compounds as to their toxic nature (Table 7). While the increase in the quantity of chlorine in

Table 6

Time (in days) of 100°/o Destruction of Test Animals in the Solutions of Tested Substances

Substance	Concentration of poison, mg/l			
	hydroids		barnacl	
	10	1	10	1
Dinitroortho cresol.	3	—	—	—
Sodium salt of F-oxide	1	+	—	—
Trichlorophenyl ether 2-4 D. . .	+	—	4	—
Tetrachlorophenyl ether 2,4,6 T.	—	—	4	—
Pentachlorophenyl ether 2,4 D .	—	—	+	—
α-naphthol thiourea	2	—	tests not conducted	
Diphenyl thiourea.	1	—		
Zinc oxide	[illegible]	—	+	—

\+ sign denotes that 50°/o and more of the tested animals perished in a given solution during the test.

the phenol derivatives decidedly intensifies their effect, the derivatives of chloroacetic acids do not have such a relation between the quantity of chlorine and the toxic effect. All of the ethers of chloroacetic acids appeared to be similarly poisonous with respect to barnacles and considerably less poisonous with respect to hydroids.

When analyzing the data presented in Table 4, one can note high toxicity of dinitric compounds. One can clearly see that the effect of these compounds can be increased by the introduction of methyl groups into the compounds. Further, by introducing sodium into the compound and obtaining more soluble salts, it was possible to increase the toxic character of dinitric derivatives of phenol.

Table 7

The Effect of Chlorine Compounds on Hydroids and Barnacles

Substance	Concentration of solutio., mg/ℓ	Weight of solution, mg/ℓ	Length of test, days	Quantity of dead animals, %	
				hydroids	barnacles
Sodium trichlorophenolate. . .	10		3	13.5	22
Sodium pentachlorophenolate. .	10		3	100	100
Calcium hypochlorite	10		3	9.1	—
Trichlorophenyl ether 2,4 D. .		10	4	66.7	100
Tetrachlorophenyl ether 2,4,6 T		10	3	14.6	100
Pentachlorophenyl ether 2,4 D.		10	3	34.1	70

Table 3 /267

The Effect of Nitric Derivatives of Phenol and the Derivatives of Thiourea on Hydroids

Substance	Concentration of solution, mg/ℓ	Weight of solution, mg/ℓ	Length of test, days	Quantity of dead animals, %	
				hydroids	barnacles
Dinitrocresol.		10	3	18.4	35
Sodium dinitroorthocresol. . .	10		3	67.7	100
Paranitrophenol.	10		3	11.8	—
α-naphthol thiourea.		10	2	64.5	—
Diphenyl thiourea.		10	1	79.8	—

The thiourea compounds appeared to be sufficiently poisonous for hydroids; whereby, the presence of phenol groups in these compounds somewhat increased the toxic effect. It is seen from Table 9 that salicylamide zinc salts and arsenical compounds appeared to be poisonous only for hydroids.

Table 9

The Effect of Anilides, Amides, Arsenical or Phosphoric Compounds, and DDT on Hydroids and Barnacles

Substance	Concentration of solution, mg/ℓ	Weight of solution, mg/ℓ	Length of test, days	Quantity of dead animals, °/o	
				hydroids	barnacles
Sodium salicyl anilide. . . .	10		3	0	—
Mixture of equal portions of zinc salicylamide and zinc dichlorosalicylamide. . . .		20	5	100	—
		10	3	50	18
Sodium salt of P-oxide. . . .		10	5	100	18
		10	1	100	—
Chlorophos(?)	10		4	—	100
	10		3	68	—
DDT	100		4	50	100

Barnacles are not sufficiently sensitive to the solutions of these salts. The chlorophos(?) and DDT solutions appeared to be more poisonous to barnacles. The introduction of the later into paints containing organic compounds as toxins improves, as is known, the antifouling properties of the paints.

In cases when the surface of a structure that comes in contact with water is well covered with paint, copper sulfate, which is a very effective poison for hydroids, may be introduced into the water. The absence of protective paint, when exposed to water containing copper compounds, may appear to be a cause of intensified corrosion. In such cases one may introduce into the water zinc oxide, which does not induce corrosion and which has a sufficiently high toxicity as regards hydroids and barnacles (Table 10). /268

Table 10

The Influence of Solutions of Inorganic Compounds and Formalin on Hydroids and Barnacles

Substance	Concentration of solution, mg/ℓ	Weight of solution, mg/ℓ	Length of test, days	Quantity of dead animals, °/o	
				hydroids	barnacles
Copper sulfate.	10		3	—	20
	10		1	100	—
Zinc oxide.		10	5	—	70
		10	3	70.5	—
40°/o Formalin.	25		1	100	97
	2.5		2	0	—

CONCLUSION

The conducted tests demonstrated that the most effective solvent for protection against fouling in Taganrogskiy zaliv of the Sea of Azov is sodium pentachlorophenolate. This substance appeared to be similarly poisonous to the hydroid polyp and cirripedian crustacean — the main foulers of this area. A slow recovery of hydroids and barnacles after having been exposed to sodium pentachlorophenolate makes it possible to apply the substance at intervals. For a correct finding of the regime and lower concentrations of the poison, it is necessary to conduct tests in a given water conduit. On the basis of the resultant experimental data, we can recommend experiments with sodium pentachlorophenolate in concentrations of 1 and 0.5 mg/ℓ. Also the application of sodium dinitroortho cresol in a concentration of 1 mg/ℓ may be recommended for the above mentioned experiments.

Taking into consideration the fact that many of the substances tested by us are characterized by selective toxicity, solutions also consisting of a mixture of organic toxins can be utilized for the above mentioned purposes, as for instance P-oxide, zinc oxide, and sodium dinitroortho cresol or the compounds of thiourea and phenyl ethers.

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THE PROBLEM OF FOULING ON PANELS IN THE BLACK SEA

Abstract

The leading forms of macrofouling on the experimental panels exposed in the Gelendzhikskaya bukhta were Membranipora, Lepralia pallasiana, Balanus improvisus, B. eburneus, Mytilus galloprovincialis, and diatoms. An average total weight of fouling was 1.23 kg/m^2.

Barnacles settling on the coal tar cover of experimental panels in summer easily pierced through it within three days. No damages to the coal tar cover by other organisms were observed.

On August 15, 1956, Ye. M. Lebedev employed experimental panels made of fiber glass for a study of the composition and quantity of multiannual fouling and for a clarification of the effect of fouling organisms on protective paints of coal tar covering the panels. Two of the panels were taken out of water on October 1, 1956 and processed; the other remained on the floating stand of the Institute of Physical Chemistry of the Academy of Sciences of the USSR in the southern part of Gelendzhikskaya bukhta 150 m north of the coast and 1 km west of the port — in a place where the bottom depth was 9 m. The panels remained in water from August 1956 to August 1958 without being raised to the surface. Altogether, 40 panels were submerged and processed. Eighteen of them, having a size of 30 x 11 cm, were at positions of +5— —40 cm from the water surface; 11 panels, having a size of 45 x 21 cm and 11 panels, having a size of 30 x 11 cm, had been submerged to depths of 90-120 cm. The panels were suspended in a vertical position. The floating stand was anchored so that no matter how intense was the wave action the deviation of the surfaces of panels from meridional positions did not exceed 10°. The outer sides of the panels were covered by three layers of coal tar. The panels were arranged in pairs. The interfaces coming in touch with each other were not painted so that, by separating the panels, it was possible to determine the extent and character of damage committed to the layer of paint by foulers.

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The main foulers were bryozoans, barnacles, mytilaceans, and diatoms. Sponges, hydroids, polychaetes, and higher algae were found in insignificant numbers on the panels. The fouling consisted of continuous and superimposed layers, which contained oval and round colonies of bryozoans of the Membranipora genus and bryozoans Lepralia pallasiana 10-30 mm in diameter. The edges of some of the bryozoan colonies formed excrescences and elevations 2-10 mm high, mainly along the bases of barnacle shells, on the tubes of serpulids and along the periphery of the panels. The settlements of bryozoans were considerable even in the first months. On the 45th day of the test, 600 to 1,000 colonies of Lepralia and 40 to 120 colonies of Membranipora were found, the former reached the size of 10 mm, the latter 11 mm in diameter.

V. N. Nikitin and Ye. P. Turpayeva (1958) report intense settlement during 1955-1956 in Gelendzhikskaya bukhta. In 1956 the quantity of bryozoans constituted 78°/o of settlers on the test panels.

The final count of bryozoan colonies on the panels of fiber glass appeared to be impossible because the colonies had been merged with one another, covering the entire surface of the panels and partly overlapping one another. The film of coal tar was not damaged by the /271 bryozoans. Two species of barnacles were found on the panels - namely, Balanus improvisus and B. eburneus. On the 45th day of the test (1 October 1956) the approximate number of barnacles at a depth of 1 m from the water surface was 200 ind/m^2, half of the number being made up of B. eburneus, the base diameter of their shells being 3 to 4 mm long. Many dead animals were found among B. improvisus; the diameter of shells did not exceed 2 mm.

Nikitin and Turpayeva (1958) also found that the settlements of larvae of barnacles were limited in Gelendzhikskaya bukhta during the 1956 season.

On the basis of the processing of panels in 1958, the maximum number of barnacles was 11,202 ind/m^2, the minimum being 127 ind/m^2.

When examining the transparent side of panels, which was not covered by coal tar, it appeared that the film of coal tar had been damaged by barnacles. The measurement of bases of the shells of barnacles, which was done by sighting through the fiber glass, showed that the cutting of the three layers of the coal tar had been made, as a rule, by B. improvisus when the base diameter of the shell was about 1.2-1.5 mm, and by B. eburneus when the diameter was 1.5 mm.

The damaging process of the film of coal tar was as follows: the cyprid larva settles on the panel and attaches to the film. The larva is transformed into a barnacle, the calcareous plates of the shell of the barnacle grow, penetrate the coal tar layer, and gradually cut through to the surface of fiber glass by its sharp edges. The barnacles attach themselves indirectly to the glass. The eccentric bases of the barnacle shells with divergent radial canals can be seen from the opposite side of the panel, which is not covered by the coal tar. Growing under the film of the coal tar, the barnacles move and force the film over themselves, due to which the film appears to be damaged; consequently, the sea water can have access to the object.

The most intense fouling was observed on the eastern tip of the stand, where 392 barnacles had occupied a panel 30 x 10 cm in size, which was nearest to the port when looking from the sea; the base diameter ranged from 1.5 to 11 mm. An approximate calculation demonstrated that about 30°/₀ of the surface of coal tar was damaged by barnacles.

B. improvisus is characterized by a rather high growth rate.

The B. improvisus individuals found in Kerchenskiy proliv reached 7.1 mm in 25 days in August (Tarasov and Zevina, 1957). The study of fouling on panels, covered by coal tar, demonstrated that the paint might have numerous damages even during the first week of exposure.

It was pointed out above that two species of barnacles were found on the panels: B. improvisus and B. eburneus. However, it was not always possible to make an accurate determination of species because empty shells of dead barnacles overgrown with bryozoans and diatom algae were most frequently found on the panels. The average quantity of live organisms was about 23°/₀. Of course, the barnacles occupied the panels in the first months after their exposure to the water, growing through the protective coating of coal tar but later the intense colonization by bryozoans suppressed the barnacles [1]. As a consequence, the greater

[1] The suppression of barnacles and other colonizing foulers, namely bryozoan membraniporans, was also noted by us (Lebedev, 1961) in the Black and Azov Seas, and by G. B. Zevina and I. V. Starostin (1962) in the Caspian Sea.

portion of the shells of the barnacles was buried under the layer of bryozoans. The settlement of barnacle larvae on panels continued during the subsequent years. Mature and young barnacles settling over the bryozoans attest to that.

A small percentage of live barnacles on the panels testify to the remote succession of the biocoenosis. As to the distribution of barnacles on the panels, it can be said that the greater portion of them had occupied the periphery of the panels. The central parts of the panels were less inhabited by barnacles.

The past succession and great age of the biocoenosis was also confirmed by the developing colonies of mytilaceans, typical of an aged fouling.

The number of mytilaceans (Mytilus galloprovincialis) on the panels varied within a wide range — from 190 to 25,255 ind/m^2.

Mytilaceans formed a layer on top of the bryozoans, two to six in a group; like barnacles, they occupied mainly the periphery of the panels. The size of mytilaceans ranged from 1 to 12 mm. However, young individuals, ranging in size from 2 to 6 mm, prevailed.

Left and right twisted Spirorbis sp., Pomatoceros triqueter L., Nereis zonata (Malmgren), and Dorvillea rubrovitatus (Grube) were found on the panels. Tiny Spirorbis (the diameter of shells ranging from 0.8 to 2 mm) was noted on the plates in amounts varying from 1 to 15.

Trihedral serpulids (reaching the length of 35 mm) were found on bryozoans. On some of the plates, the tubes of serpulids were buried under bryozoan colonies. In these cases, the bryozoans formed excrescences and elevations to 4-8 mm over the tubes of the serpulids. Groups of three to eleven serpulids were observed on the plates. The free living nereids and Dorvillea rubroviatus were found singly. Hydroids and sponges were seldom found on the panels.

Of higher algae, we found small numbers of green algae — Cladophora sp., Epicladia flustrae, and Pringsheimiella scutata, and red algae — Ceramium rubrum and Kylinia virgatula.

Of the lower algae, diatoms were represented on the panels. Their quantity was so great that a continuous layer covered bryozoans and barnacles, lending a greenish-brown hue to the surface of fouling.

In just a month after the beginning of the tests, the occupation of diatoms was clearly perceptible on the panels at a distance of 10 cm beneath the water surface. At a depth of 1 m from the water surface, the diatoms were more numerous. The following species were found on the panels.

Amphora coffeaformis Ag. var. coffeaformis

A. proteoides var. varians Pr.-Lavr.

A. granulata Greg.

A. crassa Greg. var. crassa

A. bigibba Grun. var. bigibba

Amphora sp.

Bacillaria socialis var. baltica Grun.

Caloneis liber W. Sm. var. liber

Campylodiscus Thurethii Breb.

Cocconeis scutellum Ehr. var. scutellum

C. scutellum var. parva Grun.

C. distans Greg.

Diploneis bombus Ehr. var. bombus

D. ovalis (Hilse) Cl. var. ovalis

D. smithii (Bréb.) Cl. var. smithii

Diploneis sp.

Grammatophora oceanica (Ehr.) Grun. var. oceanica

G. marina (Zyngb.) Kütz. var. marina

G. Serpentina (Ralfs) Ehr. var. serpentina

Pleurosigma elongatum W. Sm. var. elongatum

Hyalodiscus scoticus (Kütz.) Grun. var. scoticus

H. ambiguus (Grun.) var. ambiguus

Navicula scopulorum Bréb.

N. Ramosissima Ag. var. ramosissima

Nitzschia longissima (Bréb.) Ralfs var. longissima

N. punctata (W. Sm.) Grun. var. punctata

N. acuminata (W. Sm.) Grun. var. acuminata

Rhabdonema adriaticum Kutz.

Synedra tabulata (Ag.) Kütz. var. tabulata

S. tabulata var. parva (Kütz.)

S. undulata Bailey

S. baculus Hust.

S. crystallina (Ehr.) Cl. var. crystallina

Trachyneis aspera (Ehr.) Cl. var. aspera

The diatom algae found on the panels belong to two classes: Pennatae and Centricae. The predominant representatives of the class Pennatae, order Araphinales, are genera Synedra and Grammatophora, but of the order Raphinales the predominant genera are Diploneis and Amphora.

An ecological analysis of the diatoms showed that they can be assigned to four groups as regards the salinity of water (Table 1).

Table 1

The Relation of Diatoms Found on Panels to the Salinity of Water

Group	Number of species	Percentage of total number of species
Marine.	12	35
Brackish-marine	16	47
Brackish water.	3	9
Brackish-pure water	1	3
Unknown ecology	2	6
Total . . .	34	100

As to the quantity of species, the brackish-marine and marine diatoms prevail. <u>Synedra tabulata</u> var. <u>tabulata</u>, <u>Amphora coffeaformis</u> var. <u>coffeaformis</u>, <u>Caloneis liber</u> var. <u>liber</u>, which are usually observed in seas and brackish water basins, were found most frequently. A great number of the observed diatoms are euryhaline forms — altogether 21 variants, which makes up 62°/o.

Table 2

Biogeographical Forms of Diatoms Found on Panels

Group	Number of species	Percentage of total number of species
Boreal.	24	70
Warm water.	3	9
Cosmopolitan.	4	12
Black Sea only.	1	3
Unknown ecology	2	6
Total . .	34	100

The greater part of the investigated diatoms belong to boreal forms (Table 2), which are mainly found in temperate latitudes. These are _Cocconeis scutellum_ var. _scutellum_, _Grammatophora marina_ var. _marina_, _Navicula scopulorum_ var. _scopulorum_, etc. The boreal diatoms make up 70°/₀ of the total number of species.

Of all the diatoms, only _Amphora proteoides_ var. _varians_ has a limited distribution and is found only in the Black Sea.

The seasonal variations in the number of diatoms are shown in Table 3.

Table 3

Variations in Percentages of the Number of Species of Diatoms Found on Panels from August through November 1956

Species	August	November
Synedra	56	45
Cocconeis	4	4
Rabdonema	0.5	5
Grammatophora	0.5	3
Nitzschia	10	2
Others	29	41

When the panels were taken out in 1953, _Synedra_ and _Rabdonema_ were most numerous. The maximum density of the _Synedra_ population reached 1[illegible]00 cells/cm^2. The most intense greenish-brown color of diatom fouling was on bryozoans and along the edges of panels, which can, of course, be explained by a maximum development rate of algae on these parts of the panels.

The main organisms determining the fouling biomass on the panels of fiber glass were bryozoans, barnacles, and mytilaceans. On 10 of the investigated panels, the fouling biomass ranged from 0.69 to 2.27 kg/m^2. The average biomass was 1.23 kg/m^2.

The maximum value of the biomass — 2.27 kg/m^2 — was caused by the fact that the greatest mytilacean settlement was found on the panel (1000 individuals). By comparing the fouling biomass on panels taken from Sevastopol'skaya bukhta (bukhta Severnaya) with the biomass on panels taken from Gelendzhikskaya bukhta, one can see that the value of the former is 25 times greater than that of the latter. The fouling biomass of Sevastopol'skaya bukhta equalled 69.69 kg/m^2 from August 1949 to August 1950 (Dolgopol'skaya, 1954).

The fouling biomass depends mainly on the intensity and character of the initial settlement of larvae (Dolgopol'skaya, 1954). The results confirm the concept that the settlement of larvae in Gelendzhikskaya bukhta is numerically small.

As a result of the study, the following conclusions can be drawn:

1. The main fouling organisms on the panels submerged in Gelendzhikskaya bukhta were the bryozoan Membraniphora and Lepralia pallasiana, barnacles Balanus improvisus, and less often Balanus eburneus, mytilaceans Mytilus galloprovincialis, and diatom algae.

Hydroids, sponges, polychaetes, and higher algae were found in insignificant quantities, and their significance in fouling is not substantial.

2. The three day old and older barnacles (with base diameter ranging from 1.2 to 1.5 mm), that settled on the coal tar (or other paints) during the summer months, cut readily through the film, thus allowing access of sea water to the object.

3. The cutting of the protective coating of coal tar by bryozoans, mytilaceans, hydroids, polychaetes, and algae was not observed.

4. The fouling biomass that was formed during the two years on the panels ranged from 0.69 to 2.27 kg/m^2, the average being 1.23 kg/m^2. The maximum number of barnacles reached 11,200 ind/m^2, the minimum being 127 ind/m^2.

5. The biomass of the two year old panels in Sevastopol'skaya bukhta (bukhta Severnaya) was 25 times greater than the biomass in Gelendzhikskaya bukhta. This can, of course, be explained by a more intense

settlement process of larvae in Sevastopol'skaya bukhta, as well as by the abundance of foulers on the solid bottom, structures and vessels, by the protected character of the area, insignificant divergence of water with more favorable temperature and food regime for foulers, and by a greater saprogenic character of the water.

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